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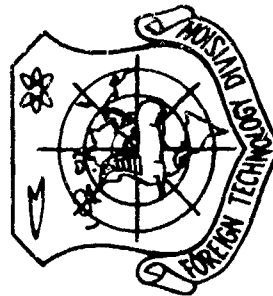
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MOSCOW. SCIENTIFIC RESEARCH INSTITUTE OF  
AEROCLIMATOLOGY. TRANSACTIONS  
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## **UNEDITED ROUGH DRAFT TRANSLATION**

MOSCOW. SCIENTIFIC RESEARCH INSTITUTE OF AEROCLIMATOLOGY.  
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CONTINUOUS DURATION OF WIND SPEEDS UNDER THE CONDITIONS OF THE PLAINS  
AREAS IN THE USSR

Voprosy Klimatologii. Nauchno-issledovatel'-  
skiy Institut Aeroklimatologii. Trudy.

T. N. Anisimova

(Problems of Climatology. Scientific-Research  
Institute of Aeroclimatology. Transactions),  
No. 52, Moscow 1968, pages 65 - 70

During recent years, in applied climatology for the obtainment of various kinds of regime characteristics, the calculation methods have become popular. On the one hand, this is explained by the lack of reliable observations on certain meteorological elements for a sufficiently prolonged period, and on the other hand by the necessity of satisfying the requirements of the practice and computing the climatic parameters in the values which can not be obtained from the direct discrete observations.

In the present report, we consider the application of the calculation methods for obtaining the regime features of continuous duration of wind speeds.

For the calculation of the spatial variation in the continuous duration of wind speeds, of great importance is an allowance for the local conditions of the location of the observation points (extent of protection, relief, vegetative cover and several other factors). As a whole, these conditions exert a more significant influence on the conditions of wind speeds than the latitudinal position of the observation points.

The direct interpolation of the hourly data (which are available in a limited quantity) for obtaining the pertinent regime features for the points not having hourly observations will involve appreciable errors in connection with the high deviations of the interpolated values as compared with the true (actual) distribution. In such cases, the application of the calculation method permits us to obtain a higher accuracy of the data.

The continuous duration of wind speeds above or below a specific level is characterized by an average and maximal continuous duration, and also by a probability of duration by gradations. All of the above-listed characteristics can be obtained

by the calculation method based on the regular interrelationship of the various wind parameters.

For obtaining the average continuous duration, we have utilized the previously established relationship [1] of this parameter with the frequency of discrete values of wind speeds which can be obtained according to the data in Spravochnik po klimatu SSSR (Handbook on USSR Climate), Part 3 (Wind) for a large number of stations.

An analysis of the hourly observations of 28 stations permitted us to differentiate this relationship with reference to a varying level of speeds ( $\leq 2$ ,  $\leq 4$ ,  $\geq 5$ ,  $\geq 8$ ,  $\geq 12$ ,  $\geq 16$  and  $\geq 20$  m/sec) for the conditions of an open level area.

In Table 1, we have indicated the values of the average continuous duration for the specific levels of wind speed. The accuracy of the indicated values will fluctuate within the limits of  $\pm 1$  hour.

Frequency	Speed (m/sec)															
	<2				<4				5				>8		>12	
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
0.1																
0.2																
0.3																
0.4																
0.5																
0.6																
0.7																
0.8																
0.9																
1													1	2	3	4
2													2	3	4	5
3													3	4	5	6
4													4	5	6	7
5													5	6	7	8
10													10	11	12	13
15													15	16	17	18
20													20	21	22	23
25													25	26	27	28
30													30	31	32	33
35													35	36	37	38
40													40	41	42	43
45													45	46	47	48
50													50	51	52	53
55													55	56	57	58
60													60	61	62	63
65													65	66	67	68
70													70	71	72	73
75													75	76	77	78
80													80	81	82	83
85													85	86	87	88

Table 1.  
(Caption on next page)

**Average Continuous Duration (Hours) of Indicated  
Limits of Wind Speeds at Their Specific Frequency  
(%)**

The value of the average continuous duration increases with an increase in frequency of any given wind speed, independent of the location of the station. However, the influence of the local conditions of the points is reflected on the value for the frequency of small wind speeds ( $\leq 2$  and  $\leq 4$  m/sec), and through it also on the continuous duration of these speeds, which increases in the well-expressed river valleys.

For the wind speeds  $\leq 2$  and  $\leq 4$  and  $\geq 5$  m/sec, the data concerning the value of the average continuous duration are presented by seasons of the year.

The presentation of the data by seasons afforded the possibility of decreasing the effect of random errors, in which we retained the typical features of the seasons. However, the data do not always correspond precisely to the calendar seasons. In the given case, the seasonality is defined more correctly not by the calendar dates, but by the pattern of any given atmospheric processes. For example, in Magadan, Krasnoyarsk and Khabarovsk, the regime of the wind speeds 5 m/sec in March progresses as in winter; the regime of the same wind speeds in Ozernyye Klyuchi, B. Yelani and Chita in May already has a summer character.

For the obtainment of the stochastic characteristics of the continuous duration of wind speeds, we utilized the method of the straightening and superposition of the integral distribution curves of the form

$$P(X \geq x) = e^{-\xi(\eta) \left(\frac{x}{\bar{x}}\right)^\eta},$$

where  $P(X \geq x)$  = the probability that the random value of  $X$  will exceed the assigned value of  $x$ ;  $x/\bar{x}$  = the ratio of the prescribed amplitude of the random value to its average value.

A detailed justification of the application of such a type of climatic processing has been presented in the report [2]. The distribution curves of the continuous duration of wind speeds have been straightened and superposed by constructing them in semibilogarithmic coordinates:

$$\left( \lg \frac{x}{\bar{x}} \text{ and } \lg \lg \frac{1}{P(X \geq x)} \right).$$

The integral curves were constructed by totalling the frequency of a definite limit of wind speed from the high values of limits of continuity to the lower values.

In the construction of the distribution curves, we took into account the modal value of frequency of continuity limits, in which we differentiated the cases with the mode, falling in the hourly range, and the cases with a mode of more than an hour.

An analysis of the derived distribution curves of continuous duration of wind speeds confirms the absence of significant differences in the distribution curves both for the various points, limits of wind speeds as well as for the seasons.

This signifies that the distribution curves, varying to some extent or other from season to season or from point to point, or finally from the wind speed values themselves, correspond to one distribution law, in which only the numerical parameters vary.

Based on the nature of the distribution, it seems feasible to us to segregate the following typical distribution curves of continuous duration (see Fig. 1):

type I-- plains type, typifying the distribution of continuous duration of various speed limits for the conditions of an open level locality with a mode equalling one hour;

type II--plains type with the mode greater than one hour, in which we can distinguish two subtypes: a- basic plains type, b- plains type with low average speeds.

The difference in the subtypes a and b consists in the fact that the entire curve b corresponds to a greater variation in the continuous duration of definite speeds.

The distribution curves with a mode occurring in the continuity range of more than an hour are constructed in most cases for the wind speeds exceeding 12 m/sec based on quite limited data. For such speeds, we typically find an abrupt reduction in observations, which in turn greatly increases the influence of random errors. In these instances, we can utilize the type I distribution curve, since the divergence from the factual data will occur only in small ranges of continuity.

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For the solution of the practical problems, of maximum interest are the ranges of high gradations of continuity, and they can be derived more reliably from the curve of type I.

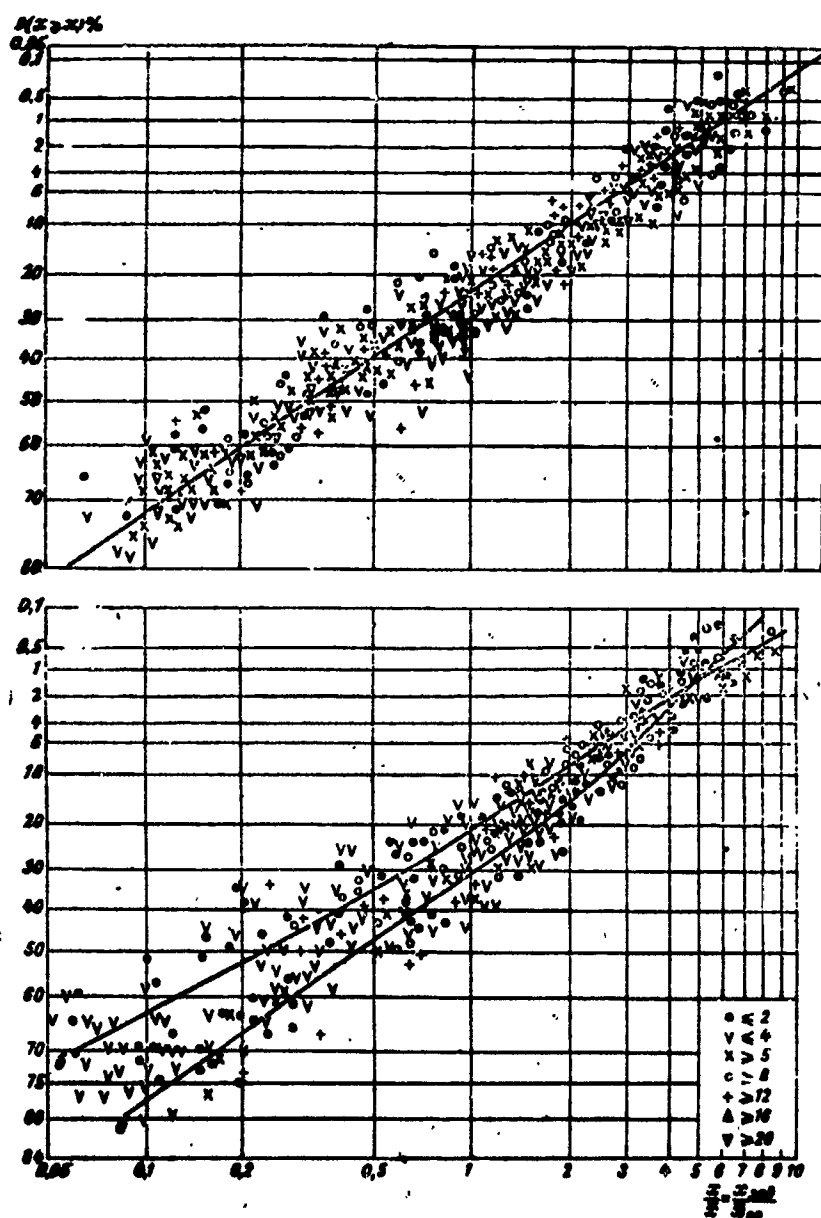


Fig. 1. Integral Distribution Curves of Probabilities of Continual Duration of Wind Speeds. Type I - plains type (top drawing), Type II - valley type (lower drawing). a- basic plains type, b- plains type with low average wind speeds.  $x_{\text{assign}}/x_{\text{av}}$  = ratio of assigned level of random value to its average value,  $\leq 2$ ,  $\leq 4$ ,  $\geq 5$ , etc. = wind speed in m/sec.

The use of the method of construction of generalized distribution curves permits us to reduce the error of probability ( $\sigma_p$ ), especially in case of a small volume of selection.

In Table 2, we present a comparison of the probability errors ( $\Delta \sigma_p$ ), of the continuous duration of wind speed in the utilization of actual data by individual station with the corresponding probability error, computed on the basis of the generalized typical curve (type I, Fig. 1).

Table 2

Number of cases	Values of $\Delta \sigma_p$									
	Ranges in continuous duration of wind speed (hours)									
	1	3	6	9	12	18	24	30	36	45
110	-2	-3	-2	-2	0					
80	-2	-2	-3	-3	-3					
60	-1	-1	0	+1	-1					
50	0	0	+1	+1	-1	+1	+1	+2		
40	+1	0	+1	+1	+1	+1	+1	+3	+2	
20	+3	+3	+4	+3	+4	+4	+5	+3	+3	+3
10	+5	+5	+4	+3	+3	+4	+4	+3	+4	
5	+15	+12	+6	+7						
3	+20	+9	+11	+14	+15					
1	+29									

The probability error ( $\Delta \sigma_p$ ) is calculated as the difference  $\sigma_p$  of the actual (according to the available number of cases) and  $\sigma_p$  based on the generalized typical (standard) curve, wherein the symbols + and - at  $\Delta \sigma_p$  indicate respectively the excess of the actual error over the computed value, and vice versa.

As is evident from the data in Table 2, at a value of selection more than 50 cases, the utilization of the actual data provides satisfactory results. In a sampling of less than 50 cases, the utilization of the calculation method becomes more effective.

This provides a basis for recommending the use of the calculation method not only in the absence of interesting information on the continuous duration, but also in the presence of factual data obtained on the basis of extremely limited samples.

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## LIST OF STATIONS

## SUPPLEMENT I

Name of stations	Location	Name of stations	Location
Artyubinsk	Plain	Linsk	Plain
Adler	Valley	Magadan	Valley
B. Yelan'	Valley	Magdagachi	"
Bykovo	Plain	Novosibirsk	Plain
Voronezh	Plain	Odessa	"
Dikson I.		Orsk	"
Irkutsk	Valley	Ozernyye Klyuchi	Valley
Kazan'	Plain	Sykt'yevsk	Plain
Koi'tsovo	Valley	Ural'sk	"
Kiev	Plain	Khabarovsk	"
Kiransk	Valley	Khar'kov	"
Krasnoyarsk	"	Chita	Valley
Kursk	Plain	Shosseynaya	Plain
Krasnodar	Valley	Yakutsk	"

APPROXIMATE CALCULATION OF WIND SPEED IN THE 100 METER ATMOSPHERIC  
SURFACE BOUNDARY LAYER FOR THE CENTRAL REGIONS OF EUROPEAN USSR

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(Problems of Climatology. Scientific Research  
Institute of Aeroclimatology. Transactions),  
NO. 32, Moscow 1963, pages 71-92

The territory under consideration in the central regions of the European USSR territory occupies the Yaroslav, Kalinin, Moscow, Vladimir, Smolensk, Kaluga, Ryazan' and Tula oblasts. In nature of relief, this territory is uniform and comprises a slightly broken plain with a series of individual uplands, including the Central Russian, Smoleno-Moscow and Valday. A large part of the territory is situated in the forest zone, and the forest-steppe is found only to the southeast of the Oka River.

As is known, the vertical profile of wind speed in the boundary layer of the atmosphere depends significantly upon the roughness of the subjacent surface, the temperature stratification and the actual wind speed.

In the present report, for the description of the variation in the wind speed with height in the 100-meter air layer, we have used a comparison of wind speed based on the wind vane of a separately selected station with a speed at a height of 100 m based on the pilot-balloon or radiosonde data taken from the charts in conformity with the location of the station.

On the basis of the studies, we have included data on the average speeds of wind and frequency at 77 stations on the ground in the central regions, seven pilot-balloon stations and 18 stations (USSR territory) of the radiosonde observations. For the list of aerological stations, refer to Supplement 2. The data from the ground stations pertain to the period 1936-1960; the aerological data, 1930-1952 (pilot balloon) and 1959-1963 (radiosonde).

The description of the location of stations based on the standard system developed by S. A. Sapozhnikova [10] has been presented in the section on climate of the UGMS of the Central Regions by L. D. Solov'yeva under the supervision of P. B. Shekhtman. Ye. Yu. Kim participated in the calculation of the tables included in the text.

In the process of formulating the description of the stations' location based on the standard system [10] (refer to Supplement 1), the necessity was indicated of making certain refinements. Thus, in column 4, explaining the landscape of the locality, the swampiness "B" is refined further. In addition, in the description of the macro- and meso-roughness, we introduce additionally the column "extent of forest cover, extent of builtup area"--ZL, ZS. In this connection, the lower index at the conventional notation ZL, ZS characterizes in points the part of the area occupied by woods or buildings, of the total area with a radius of 10 km.

Part of Area	Points
0 to 1/4	1
from 1/4 to 3/4	2
from 3/4 to 1	3

The exponent at the conventional notation indicates the point evaluation of the height of trees of buildings. /72

Height	Points
Less than 10 m	1
More than 10 m	2

(In either case, point 1 is dropped).

In the description of a water basin (reservoir), we have introduced the column "Form of shoreline":

Form of shoreline	Conventional symbols
Cape	M
Gulf	Z

In the description of the relief, we have introduced the additional form, i.e. the lowland "N".

Based on the description of the location of each of the 77 stations, we have accomplished a standardization of location.

All the stations are classified according to the zonal features of the location (the forest and forest-steppe), upon the local extent of protection (open and protected), based on the relief form (level location, elevated points, hill, slope, valley, straight valley, depression, etc.), proximity of water basin (reservoir, lake) and shape of shoreline (cape). In addition, in the standardization we have separately classified the forest glade and the urban conditions. In the grouping of the stations based on these characteristics, we have taken into consideration the average annual wind speed and the diurnal amplitude of wind speed in July ( $\bar{v}_{13}/\bar{v}_1$ ).

In connection with the fact that the heights of the wind vanes at the meteorological stations vary from 8 to 26 m, in the standardization for the comparability of the data, the difference in the heights was compensated by multiplication times the appropriate factor computed on the basis of the logarithmic formula at  $z_0 = 1$  m. In this manner, the average speeds were reduced to the height of 10 m. As a result of the standardization, we derived the generalized estimations of the indexes of the wind regime in the basic types of location which are listed in Table 1. As is evident from the data in the table, independently of the conditions of the extent of cover, the average annual wind periods will increase from the concave relief forms to the convex forms, and reach the maximum values (4-4.7 m/sec) in the places situated near the water bases. The index of the characteristic of the diurnal pattern of wind speed in July  $v_{13}/v_1$  has a reverse pattern, i.e. the maximum values occur in the depressed points (depression, forest glade), while the lowest values (0.9-1.4 m/sec) are found on the elevated points and near the water basins. The line which is segregated in the protected conditions, oriented in the direction of the prevalent winds, has average indexes of the wind regime close to the convex relief forms (hills, slope), wherein the speed is even slightly higher (3.6 m/sec).

For the approximate description of the variation in wind speed with height in the 100-m layer, we calculated the ratios of wind speeds at heights of 100 m to the wind speed at 10 m.

$$A = v_{100}/v_{10} \quad (1)$$

The average wind speeds at a height of 10 m are taken from the wind vane of individual stations, wherein for comparability with the aerological data, they are calculated as an average from the observations at 0700 and 1900 hours.

Table 1

Average Annual Wind Speed ( $v_{\text{year}}$ ) and Diurnal Amplitude of Speed in July in the Basic Types of Station Locations (UGMS) of the Central Observatory

Zone	Extent of shelter	Relief feature	$\overline{v_{\text{year}}}$ (m/sec)	$\frac{v_{\text{max}}}{v_{\text{min}}}$	Number of stations
Forest	Exposed	Level locality.....	3.8	2.3	13
		Forest glade. . . .	2.9	3.2	2
		Depression. . . .	3.3	3.1	2
		Lower part of valley slope. . . .	3.5	2.5	3
		Elevated points. . . .	4.0	2.2	3
		High shore of river..	4.7	2.0	2
		Reservoir, lake.....	4.1	1.4	2
		Cape.....	4.7	0.9	1
		Level locality.....	3.1	2.4	14
		Forest glade.....	2.2	2.9	1
		Urban sheltered conditions.....	2.5	2.3	3
		Urban conditions, hill	3.2	1.8	1
		Basin.....	3.0	3.7	2
		Valley.....	3.2	2.8	4
		Straight valley.....	3.6	2.4	2
		Hill, slope.....	3.4	2.4	8
		Reservoir, lake.....	3.6	1.9	4
Forest-steppe	Exposed	Level locality.....	4.0	2.2	3
		Elevated points.....	4.7	2.0	3
	Sheltered	Urban sheltered conditions.....	3.1	2.1	1
		Valley.....	4.1	2.2	1
		Hill, slope.....	4.3	2.1	1

For the calculation of R, the average speeds at a height of 100 m for all 77 stations of ground observations are taken from the charts compiled by us on the basis of the climatologically generalized pilot-balloon data of three stations (Moscow, Vologoye, Smolensk), situated in the territory under consideration, and four stations (Vologda, Gor'kiy, Orel, **Velikiye Laki**) in the adjoining territory.

As a result of the calculation, we derived the annual pattern of the R-values under various conditions of location in the plains and hilly regions of the Central oblasts (Table 2). As is evident from the data in Table 2, the R-values are higher in the forest zone than in the forest-steppe zone, and higher under protected conditions than in the exposed ones. The maximum values of the ratios for R (3.0-3.5) are noted in the forest glades, in the places protected by buildings, and in the depressions. The lowest values for R (1.1-1.2) are

found near the large water basins. In the annual pattern, the R-values increase from winter to summer, and reach their maximum in August-September. Also perceptible is a certain increase in R in April. Such a pattern in the R-values is explained both by the general circulatory processes and by the influence exerted by the underlying surface. The indicated increase in R during April is associated with the decrease in the average wind speeds at the Earth as a result of the descent of the snow cover and the increase in the roughness of the ground surface, whereas at a height of 100 m, during this period, the maximum values of the winter months are retained.

Table 2

2-Values Under Various Conditions of Terrain in Plains and Hilly Regions  
in the Central Oblasts of USSR European Territory

Relief feature	Forest zone												Forest-steppe												Year 1951
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	

Exposed																									
Level areas.....	1.6	1.6	1.7	2.0	1.8	1.9	2.0	2.3	2.2	1.8	1.7	1.6	1.5	1.5	1.6	1.8	1.7	1.8	1.8	2.1	2.1	1.8	1.7	1.5	1.7
Forest glade.....	2.3	2.1	2.2	2.5	2.3	2.3	2.5	3.0	2.7	2.3	2.2	2.1	2.3												1.7
Basin.....	1.7	1.7	1.9	2.1	2.0	2.0	2.4	2.7	2.6	1.9	1.7	1.7	2.0												
Lower part of valley slope.....	1.6	1.6	1.8	2.0	1.9	2.1	2.3	2.5	2.3	1.8	1.7	1.7	2.0												
Elevated areas.....	1.4	1.4	1.5	1.8	1.6	1.7	1.8	2.1	1.9	1.6	1.5	1.4	1.7												
High river bank.....	1.2	1.2	1.3	1.5	1.5	1.5	1.6	1.7	1.7	1.5	1.3	1.2	1.4												
Reservoir, lake.....	1.5	1.5	1.5	1.8	1.4	1.5	1.5	1.6	1.5	1.5	1.4	1.5	1.5												
Cape.....	1.2	1.3	1.4	1.7	1.4	1.4	1.3	1.4	1.1	1.1	1.1	1.2	1.3												

Sheltered																									
Level areas.....	1.9	1.9	2.0	2.2	2.0	2.1	2.3	2.6	2.4	2.0	1.9	1.9	2.1												
Forest glade.....	2.7	2.6	2.7	2.9	2.3	2.6	2.8	3.5	3.2	2.7	2.7	2.6	2.8												
Urban sheltered conditions.....	2.4	2.2	2.4	2.7	2.5	2.6	2.7	3.0	3.0	2.4	2.4	2.4	2.6												
Urban conditions, hill Trough.....	1.7	1.9	1.9	2.5	2.1	2.4	2.2	2.6	2.5	2.0	2.0	1.9	2.2												
Valley.....	2.0	2.0	2.1	2.4	2.2	2.3	2.5	3.0	3.0	2.2	2.0	1.9	2.3												
Shaded hill valley.....	1.9	1.9	2.1	2.3	2.2	2.3	2.4	2.9	2.7	2.2	2.0	1.9	2.2												
Hill, slope.....	1.4	1.6	1.7	2.1	1.8	1.9	2.0	2.3	2.2	1.8	1.6	1.5	1.8												
Reservoir, lake.....	1.6	1.7	1.8	2.1	1.9	1.9	2.2	2.5	2.3	1.8	1.7	1.7	1.9												
	1.6	1.6	1.8	2.0	1.8	1.9	2.0	2.2	2.0	1.6	1.6	1.6	1.3												

Table 3

# Daylight Values for Central Regions (Oblasts) of USSR European Territory

Relief feature	Forest zone												Forest-steppe												Year For	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		
Exposed																										
Level area.....	1.6	1.6	1.7	2.3	2.2	2.5	2.7	2.8	2.6	1.8	1.7	1.6	2.1	1.5	1.5	1.6	2.0	1.9	2.0	2.0	2.5	2.5	1.8	1.7	1.5	1.9
Forest glade.....	2.3	2.1	2.2	3.1	3.3	3.3	3.8	3.9	3.4	2.3	2.2	2.1	2.8													
Trough.....	1.7	1.7	1.9	2.5	2.7	2.7	3.5	3.4	3.2	1.9	1.7	1.7	2.4													
Lower part of valley slope.....	1.6	1.6	1.8	2.3	2.5	2.9	3.3	3.1	2.8	1.8	1.7	1.7	2.3													
Elevated areas.....	1.4	1.4	1.5	2.0	1.9	2.1	2.2	2.5	2.2	1.6	1.5	1.4	1.8													
High riverbank.....	1.2	1.2	1.3	1.6	1.7	1.7	1.9	1.9	1.9	1.5	1.3	1.2	1.5													
Reservoir, lake.....	1.5	1.5	1.5	2.0	1.6	1.7	1.7	1.7	1.5	1.4	1.4	1.5	1.6													
Cape.....	1.2	1.3	1.4	1.9	1.6	1.6	1.5	1.5	1.1	1.1	1.1	1.2	1.4													
Sheltered																										
Level area.....	1.9	1.9	2.0	2.6	2.7	2.9	3.3	3.2	2.9	2.0	1.9	1.9	2.4													
Forest glade.....	2.8	2.7	2.8	3.7	3.3	4.0	4.5	4.9	4.3	2.8	2.8	2.7	3.4													
Urban sheltered conditions	2.5	2.2	2.5	3.4	3.8	4.0	4.3	3.9	3.9	2.5	2.5	2.5	3.2													
Urban conditions hill	1.7	1.9	1.9	3.1	2.9	3.5	3.1	3.2	3.1	2.0	2.0	1.9	2.5													
Trough.....	2.0	2.0	2.1	2.9	3.1	3.1	3.8	3.9	3.4	2.2	1.9	1.9	2.7													
Valley.....	1.9	1.9	2.1	2.8	3.1	3.3	3.5	3.7	2.6	1.8	1.6	1.5	2.6													
Daylight valley.....	1.4	1.6	1.7	2.5	2.8	2.5	2.7	2.8	2.8	1.8	1.6	1.5	2.1													
Hill, slope.....	1.6	1.7	1.8	2.5	2.5	2.5	3.1	3.1	2.3	1.6	1.7	1.7	2.2													
Reservoir, lake.....	1.6	1.6	1.8	2.3	2.2	2.5	2.7	2.6	2.3	1.6	1.6	1.6	2.0													

Relief feature	Forest zone												Forest-steppe												Year For	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		
Exposed																										
Level area.....	1.6	1.6	1.7	2.3	2.2	2.5	2.7	2.8	2.6	1.8	1.7	1.6	2.1	1.5	1.5	1.6	2.0	1.9	2.0	2.0	2.5	2.5	1.8	1.7	1.5	1.9
Forest glade.....	2.3	2.1	2.2	3.1	3.3	3.3	3.8	3.9	3.4	2.3	2.2	2.1	2.8													
Trough.....	1.7	1.7	1.9	2.5	2.7	2.7	3.5	3.4	3.2	1.9	1.7	1.7	2.4													
Lower part of valley slope.....	1.6	1.6	1.8	2.3	2.5	2.9	3.3	3.1	2.8	1.8	1.7	1.7	2.3													
Elevated areas.....	1.4	1.4	1.5	2.0	1.9	2.1	2.2	2.5	2.2	1.6	1.5	1.4	1.8													
High riverbank.....	1.2	1.2	1.3	1.6	1.7	1.7	1.9	1.9	1.9	1.5	1.3	1.2	1.5													
Reservoir, lake.....	1.5	1.5	1.5	2.0	1.6	1.7	1.7	1.7	1.5	1.4	1.4	1.5	1.6													
Cape.....	1.2	1.3	1.4	1.9	1.6	1.6	1.5	1.5	1.1	1.1	1.1	1.2	1.4													
Sheltered																										
Level area.....	1.9	1.9	2.0	2.6	2.7	2.9	3.3	3.2	2.9	2.0	1.9	1.9	2.4													
Forest glade.....	2.8	2.7	2.8	3.7	3.3	4.0	4.5	4.9	4.3	2.8	2.8	2.7	3.4													
Urban sheltered conditions	2.5	2.2	2.5	3.4	3.8	4.0	4.3	3.9	3.9	2.5	2.5	2.5	3.2													
Urban conditions hill	1.7	1.9	1.9	3.1	2.9	3.5	3.1	3.2	3.1	2.0	2.0	1.9	2.5													
Trough.....	2.0	2.0	2.1	2.9	3.1	3.1	3.8	3.9	3.4	2.2	1.9	1.9	2.7													
Valley.....	1.9	1.9	2.1	2.8	3.1	3.3	3.5	3.7	2.6	1.8	1.6	1.5	2.6													
Daylight valley.....	1.4	1.6	1.7	2.5	2.8	2.5	2.7	2.8	2.8	1.8	1.6	1.5	2.1													
Hill, slope.....	1.6	1.7	1.8	2.5	2.5	2.5	3.1	3.1	2.3	1.6	1.7	1.7	2.2													
Reservoir, lake.....	1.6	1.6	1.8	2.3	2.2	2.5	2.7	2.6	2.3	1.6	1.6	1.6	2.0													

Table 4

Daytime R-Values for Central Climates (Regions) of USSR European Territory

Relief Features	Forest zone												Forest steppes														
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	
Exposed																											
Level areas.....	1.5	1.5	1.3	1.5	1.4	1.5	1.5	1.7	1.6	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.6	1.6	1.6	1.6	1.4	1.4	
Forest glade.....	2.1	1.9	1.8	1.8	1.7	1.7	1.8	2.0	1.8	1.9	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	
Trough.....	1.6	1.6	1.6	1.6	1.5	1.5	1.7	1.8	1.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	
Lower part of valley slope.....	1.5	1.5	1.5	1.5	1.5	1.6	1.7	1.8	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	
Elevated areas.....	1.3	1.3	1.3	1.4	1.3	1.4	1.4	1.6	1.5	1.4	1.4	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	
High river bank.....	—	—	—	1.1	1.2	1.2	1.2	1.3	1.4	1.3	1.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Reservoir, lake.....	1.4	1.4	1.3	1.4	1.2	1.2	1.2	1.3	1.2	1.2	1.3	1.4	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.4	1.4	1.2	1.3	1.3	1.3		
Cape.....	—	1.2	1.2	1.4	1.2	1.2	1.1	1.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Sheltered																											
Level areas.....	1.7	1.7	1.7	1.8	1.5	1.6	1.7	1.8	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.9	1.7	1.7	1.7	
Forest glade.....	2.4	2.3	2.2	1.9	1.7	1.9	1.9	2.2	2.1	2.2	2.3	2.5	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	
Urban sheltered conditions.....	2.2	2.0	2.0	1.8	1.8	1.8	1.8	2.0	2.0	2.0	2.2	2.2	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	
Urban conditions, hill.....	1.6	1.7	1.6	1.8	1.5	1.7	1.6	1.8	1.8	1.7	1.8	1.7	1.7	1.8	1.7	1.8	1.7	1.8	1.7	1.8	1.8	1.8	1.9	1.7	1.7	1.7	
Trough.....	1.8	1.8	1.8	1.7	1.6	1.6	1.8	2.0	2.0	2.0	1.8	1.7	1.7	1.8	1.8	1.7	1.8	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	
Valley.....	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	
Shaded valley.....	1.3	1.5	1.5	1.6	1.4	1.5	1.5	1.7	1.6	1.5	1.5	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
Hill, slope.....	1.5	1.6	1.6	1.6	1.5	1.5	1.6	1.8	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	
Reservoir, lake.....	1.5	1.5	1.5	1.5	1.4	1.5	1.5	1.6	1.5	1.4	1.5	1.5	1.5	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.3	1.3	1.3	1.3	

The displacement in the R-maximum at the end of summer (August) is evidently explained by the fact that we utilize the observation hours 0700 and 1900, when owing to the late sunrise and the early sunset, there is expressed more distinctly than in June and July the weakening of the turbulence associated with the temperature inversions.

The variation in the course of a 24-hour period of the wind profile in the 100-meter layer can be regarded as a function of the wind speed at the height of 100 m and of thermal stratification. Moreover, R is established directly by the wind speeds at heights of 10 and 100 m.

The phases of the diurnal pattern do not coincide at the height of 10 and 100 m. While at a height of 10 m, the minimum of speed occurs in the night hours, while the maximum occurs in the daytime hours, at a height of 100 m, the maximum is recorded in the night hours, while the minimum occurs in the morning hours.

In Figs. 1 and 2, we have presented the ratios

$$\rho = R_n / \bar{R}, \quad (2)$$

where  $R_n$  = the ratio of speeds in the daytime (Fig. 1) and night (Fig. 2) hours,  $\bar{R}$  = the average ratio of speeds for a 24 hour period.

For the construction of the curves, we have utilized the data from the radiosonde observations from 12 stations.

As is evident in Figs. 1 and 2, to a known extent the  $\rho$ -value depends on  $\bar{R}$ . During the daytime hours,  $\rho$  decreases with an increase in  $\bar{R}$ . During the night, on the other hand, it increases. Moreover,  $\rho$  varies in its annual pattern. In the night hours,  $\rho$  increases from winter to summer, and on the other hand in the daylight hours, it decreases. Utilizing the derived dependence of  $\rho$  on  $\bar{R}$ , we obtained an approximate characteristic of the values in the nocturnal and daytime hours for the various types of location (Tables 3, 4). The data presented in Tables 3 and 4 indicate that the maximum differences in R during the night hours from the daytime hours occur in the summer period. In winter, the difference in R at night as compared with day are not significant, and comprise 0.2-0.4. However, in summer these differences are great, especially under the protected conditions, where the R-values during the night hours exceed by more than twice the daytime values (forest glade, urban protected conditions). It should be remarked that in the annual pattern, the R-values during the night hours have a considerable range (1.2-1.4 = level area, 2.0-2.2 = forest glade, depression), while during the daytime hours, the range of the annual pattern is slight, around 0.2-0.4, and only under the

protected conditions does it reach 0.8. Although the annual pattern for R is slight during the daytime hours, for almost all types of locality, we can detect a decrease in R at the end of spring and the beginning of summer.

Such a pattern of the calculated R-values is confirmed by the data obtained directly from the radiosonde observations for the Dolgoprudnaya Station (Table 5), which is located on a level place, but surrounded by forest and structures at a distance of 50-500 m.

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R-Values at Various Hours of the Day for the Dolgoprudnaya Station

Time (hours)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2.5	2.9	3.2	3.2	4.1	4.7	4.9	5.6	5.9	5.7	5.3	2.9	2.9
8.5	2.9	2.9	2.8	2.5	2.0	2.1	2.2	2.6	2.5	3.4	2.9	2.8
14.5	2.6	2.1	2.0	2.1	1.9	2.1	2.0	2.1	2.3	2.5	2.7	3.2
20.5	2.9	2.9	3.2	4.0	3.9	4.3	4.4	5.5	6.2	4.8	3.2	3.0

The derived relationships of wind speeds on an average for 24 hours, during the night and daytime hours provide the opportunity, if we have the average wind speed at the wind vane height, of calculating the wind speed at a height of 100 m depending on the features of the location and with allowance for the diurnal pattern.

In addition, these relationships permitted us to utilize them for an approximate description of the wind speed at a height of 50 m. For the calculation of the wind speed at this height, we used the power formula of the variation in wind speed with height

$$\frac{v}{v_1} = \left(\frac{z}{z_1}\right)^m \quad (3)$$

In report [3], it was shown that the wind profile up to H = 200-300 m is approximated somewhat more accurately with the aid of the power function of height than with the aid of the logarithmic function. The exponent m of the power function was regarded by us a function not only of the thermal stratification but also of the features of the underlying surface. The values of the exponent m, both on an average for a day as well as for the day and night, was determined on the basis of R. Substituting the derived m-values into the power equation, we calculated R for day, night and on an average for 24 hours at a height of 50 m (Tables 6, 7, and 8). For verifying the magnitude of the



Fig. 1. Dependence of Post-Midnight  $\rho$ -Values Upon R. I- summer, II- transient period, III- cold period; 1- May-July, 2- April, August-September, 3- October-March.

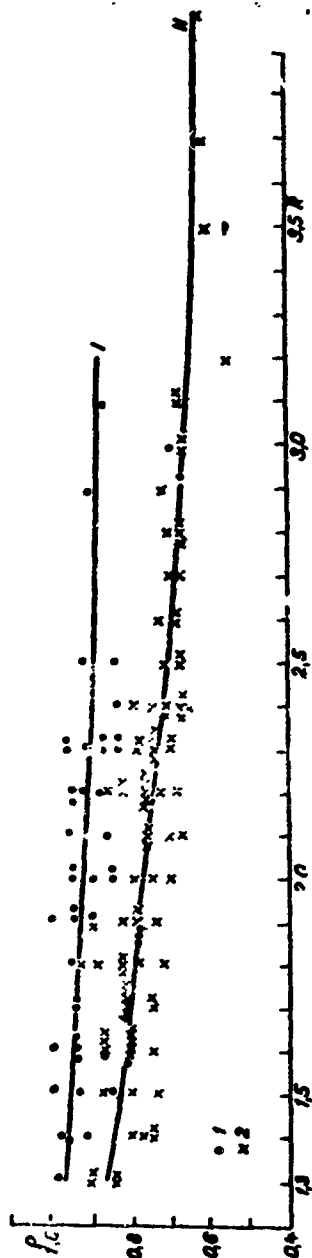


Fig. 2. Dependence of Afternoon  $\rho$ -Values on R. I- cold period, II- warm period; 1- January-March, 2- April-October.

values derived, the latter were compared with the calculated data [8] according to the Laykhtman formula:

$$\frac{u}{u_1} = \frac{\lg z - \lg z_0}{\lg z_1 - \lg z_0}, \text{ at } z_0 = 0.05 \text{ and } 3 \text{ cm} \quad (4)$$

for an open level place at a latitude of 45-50°. A comparison indicated that the magnitude of the ratios agrees well with the data in Tables 7 and 8 for a level place in the forest-steppe, and this permits us to recommend them in a first approximation for practical utilization.

In the present paper, we have examined the question of the employment of the average wind speeds for obtaining the maximal speeds at a height of 100 m. For this purpose, we applied the graphic method (adopted in climatology) of the smoothing and extrapolation of series of observations based on the grid (network) developed by L. Ya. Anapol'skaya and L. S. Gandin. According to the data of 18 stations of radiosonde observations, we constructed the distribution curves of wind speed based on the wind vane and at a height of 100 m. It turned out that the angle of inclination to the axes of the coordinates for the distribution curve of wind speed at a height of 100 m differs from the inclination angle at the Earth—the line runs more evenly—therefore at high speeds, the distribution lines converge, and this indicates a relatively decreased variation in the wind speed at a height of 100 m. This is possibly the result of the varying scale in the averaging of the data (of the anemometer and the radiosonde). With the aid of the distribution curves, for 18 stations we establish the relationship of frequency of high wind speeds to the average speed (Fig. 3). This graph illustrates well the differences in the variation of speeds at the heights of 10 and 100 m, which increase in proportion to the increase in the speed. Thus, the probability curves of speed  $\geq 7$  m/sec at these heights are an extension of each other. However, the lines characterizing the increase in the probability of speed  $\geq 10, 15, 20$  m/sec at a height of 100 m, located below the corresponding lines based on the wind vane, which is a manifestation of the decrease in the variation of wind speed with height. Based on the data from this curve, we constructed a nomogram for calculating the maximal wind speeds at a height of 100 m (Fig. 4). Based on this nomogram, we can determine the maximal wind speed at a height of 100 m, provided that we know the average wind speed.

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In conclusion, we should state that, in spite of the approximation of the calculations, the data presented testify to a considerable variation in the wind profile in the lower

Table 6

R<sub>50</sub>-Average Values for Central Regions of USSR European Territory

Relief Features	Forest zone												Forest steppe												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Exposed																									
Level area.....	1.4	1.4	1.4	1.6	1.5	1.5	1.6	1.8	1.7	1.5	1.4	1.4	1.5	1.3	1.3	1.4	1.5	1.4	1.5	1.5	1.7	1.7	1.5	1.4	1.3
Forest glade.....	1.8	1.7	1.7	1.9	1.8	1.8	1.9	2.2	2.0	1.8	1.7	1.7	1.8												
Through.....	1.4	1.4	1.5	1.7	1.6	1.6	1.8	2.0	2.0	1.5	1.4	1.4	1.6												
Lower part of valley slope.....	1.4	1.4	1.5	1.6	1.5	1.7	1.8	1.9	1.8	1.5	1.4	1.4	1.6												
Elevated areas.....	1.2	1.2	1.3	1.5	1.4	1.3	1.7	1.5	1.4	1.3	1.2	1.4													
High river bank.....	1.0	1.0	1.1	1.3	1.3	1.3	1.4	1.4	1.4	1.3	1.1	1.0	1.2												
Reservoir, lake.....	1.3	1.3	1.3	1.5	1.2	1.3	1.3	1.4	1.3	1.2	1.2	1.3	1.3												
Cape.....	1.0	1.1	1.2	1.4	1.2	1.2	1.1	1.2	1.0	1.0	1.0	1.0	1.1												
Sheltered																									
Level area.....	1.5	1.5	1.6	1.7	1.6	1.7	1.8	2.0	1.8	1.6	1.5	1.5	2.7												
Forest glade.....	2.0	2.0	2.0	2.1	1.8	2.0	2.1	2.4	2.2	2.0	2.0	2.0	2.1												
Urban sheltered conditions.....	1.8	1.7	1.8	2.0	1.9	2.0	2.0	2.2	2.2	1.8	1.8	1.8	2.0												
Urban conditions, hill through.....	1.4	1.5	1.5	1.9	1.7	1.8	1.7	2.0	1.9	1.6	1.6	1.5	1.7												
Through.....	1.6	1.6	1.7	1.8	1.7	1.7	1.9	2.2	2.2	1.7	1.5	1.5	1.8												
Straight valley.....	1.5	1.5	1.7	1.8	1.7	1.8	1.8	2.1	2.0	1.7	1.6	1.5	1.7												
Through.....	1.1	1.1	1.4	1.7	1.5	1.5	1.6	1.8	1.7	1.5	1.4	1.3	1.5												
Hill, slope.....	1.4	1.4	1.5	1.7	1.5	1.5	1.7	1.9	1.8	1.5	1.4	1.4	1.5												
Reservoir, lake.....	1.4	1.4	1.5	1.6	1.5	1.5	1.6	1.7	1.6	1.4	1.4	1.4	1.5												

Table 7

R<sub>50</sub>-Night Time Values for Central Regions of USSR European Territory

Relief Features	Forest zone												Forest steppe													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Exposed																										
Level area.....	1.4	1.4	1.4	1.8	1.7	1.9	2.0	2.1	2.0	1.5	1.4	1.4	1.7	1.3	1.3	1.4	1.6	1.5	1.6	1.6	1.9	1.9	1.5	1.4	1.3	1.5
Forest glade.....	1.8	1.7	1.7	2.2	2.3	2.3	2.5	2.6	2.4	1.9	1.7	1.7	2.1													
Trough.....	1.4	1.4	1.5	1.9	2.0	2.0	2.4	2.4	2.2	1.5	1.4	1.4	1.8													
Lower part of valley slope.....	1.4	1.4	1.5	1.8	1.9	2.1	2.3	2.2	2.1	1.5	1.4	1.4	1.8													
Elevated areas.....	1.2	1.2	1.3	1.6	1.5	1.7	1.7	1.9	1.7	1.4	1.3	1.2	1.5													
High river bank.....	1.0	1.0	1.1	1.4	1.4	1.5	1.5	1.5	1.3	1.1	1.0	1.0	1.3													
Reservoir, lake.....	1.3	1.3	1.3	1.6	1.4	1.4	1.4	1.4	1.3	1.2	1.2	1.3	1.4													
Cape.....	1.0	1.1	1.2	1.5	1.4	1.4	1.3	1.3	1.0	1.0	1.0	1.0	1.1													
Sheltered																										
Level area.....	1.5	1.5	1.6	2.0	2.0	2.1	2.3	2.2	2.1	1.6	1.5	1.5	1.8													
Forest glade.....	2.1	2.0	2.1	2.5	2.3	2.6	2.8	3.0	2.8	2.1	2.1	2.0	2.4													
Urban sheltered conditions.....	1.9	1.7	1.9	2.4	2.5	2.6	2.8	2.6	2.6	1.9	1.9	1.9	2.2													
Urban conditions, hill	1.4	1.5	1.5	2.2	2.1	2.4	2.2	2.2	2.2	1.6	1.6	1.5	1.9													
Trough.....	1.6	1.6	1.7	2.1	2.2	2.2	2.5	2.6	2.6	1.7	1.5	1.5	2.0													
Valley.....	1.5	1.5	1.7	2.1	2.2	2.3	2.4	2.5	2.4	1.7	1.6	1.5	2.0													
Straight valley.....	1.2	1.4	1.4	1.9	2.1	1.9	2.0	2.1	2.0	1.5	1.4	1.3	1.7													
Hill, slope.....	1.4	1.4	1.5	1.9	1.9	1.9	2.2	2.2	2.1	1.5	1.4	1.4	1.7													
Reservoir, lake.....	1.4	1.4	1.5	1.8	1.7	1.9	2.0	2.0	1.8	1.4	1.4	1.4	1.6													

Table 8

R<sub>50</sub>-Daytime Values for Central Regions of USSR European Territory

Relief Features	Forest zone												Forest-steppe													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
	Exposed												Sheltered													
Level area.....	1.3	1.3	1.3	1.3	1.2	1.3	1.3	1.4	1.4	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.4	1.4	1.4	1.4	1.2	1.2
Forest glade.....	1.7	1.5	1.5	1.5	1.4	1.4	1.5	1.6	1.5	1.5	1.6	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.2	1.2
Trough.....	1.4	1.4	1.4	1.4	1.3	1.3	1.4	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.1	1.1
Lower part of valley slope.....	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.2	1.2	1.0	1.1	1.1	1.1
Elevated areas.....	1.1	1.1	1.1	1.2	1.1	1.2	1.2	1.4	1.3	1.2	1.2	1.2	1.1	1.2	1.1	1.0	—	—	—	—	—	—	—	—	—	—
High river bank.....	—	—	1.0	1.0	1.0	1.0	1.1	1.2	1.2	1.1	1.0	1.1	1.0	1.2	1.1	1.0	—	—	—	—	—	—	—	—	—	—
Reservoir, lake.....	1.2	1.2	1.1	1.2	1.0	1.0	1.0	1.1	1.0	1.0	1.1	1.2	1.1	1.2	1.1	1.0	—	—	—	—	—	—	—	—	—	—
Cape.....	—	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sheltered																										
Level area.....	1.4	1.4	1.4	1.5	1.3	1.4	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.4	1.4
Forest glade.....	1.8	1.8	1.7	1.5	1.4	1.5	1.5	1.7	1.7	1.7	1.7	1.8	1.9	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.5	1.5	1.5	1.5	1.4	1.4
Urban sheltered conditions.....	1.7	1.6	1.6	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.7	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.4	1.4	1.4	1.4	1.4	1.4
Urban conditions, hill. Trough.....	1.4	1.4	1.4	1.5	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.2	1.2
Valley.....	1.5	1.5	1.5	1.4	1.4	1.4	1.5	1.6	1.6	1.6	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.2	1.2
Straight valley.....	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.2	1.2
Hill, slope.....	1.1	1.3	1.3	1.4	1.2	1.3	1.3	1.4	1.5	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.1	1.1
Reservoir, lake.....	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.1	1.1	1.1	1.1	1.1	1.1

100-meter layer both in space and in time. The variation in the R-value in the territory under consideration both in time and in space is established not only by the local features of the underlying surface but also by the weather conditions, particularly the thermal stratification.

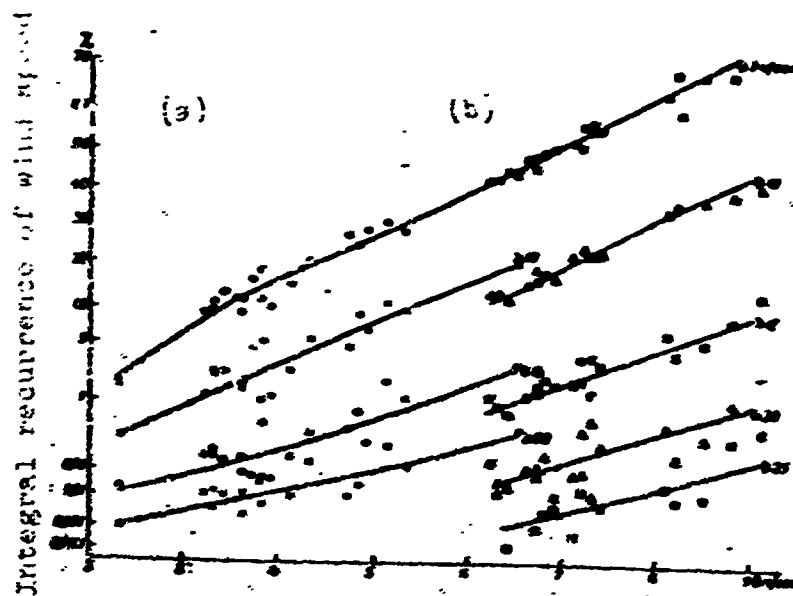


Fig. 3. Wind-speed probability  
 ( 7, 10, 20, 25m/s ) as a function of average  
 wind speed by vane (a) at 100 m (b)

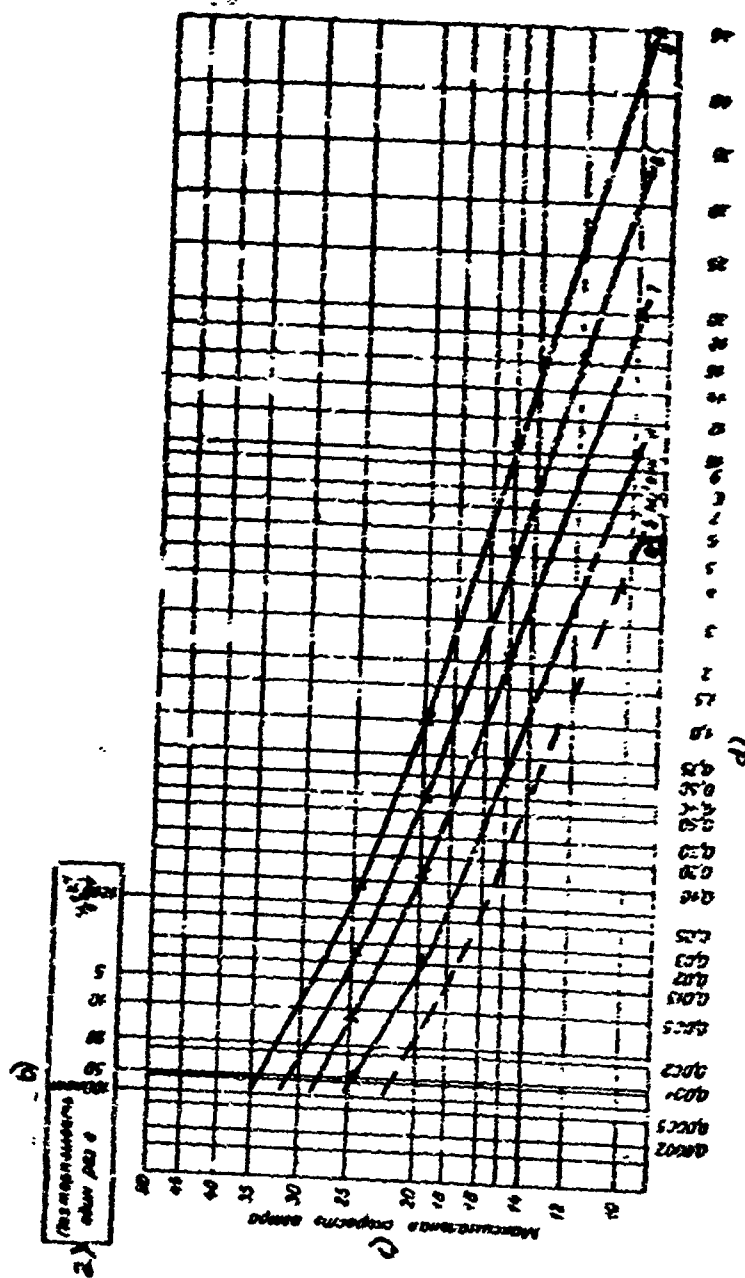


Fig. 4. Nomogram for Calculating the Maximal Wind Speeds ( $v_m/\text{sec}$ ) based on the Average Speed ( $V_n/\text{sec}$ ) for the Height of 100 m.  
Key: a) frequency once per; b) 100 years, etc.; c) maximal wind speed; d) integral frequency of wind speeds, 5; and e) 5 m/sec.

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NOT REPRODUCIBLE

# FEATURES OF TERRAIN SURROUNDING THE WEATHER STATIONS AND PRINCIPAL WIND CHARACTERISTICS

Station	Height of location, (m)	Wind vane height (m)	Macro-roughness		
			General (landscape)	Density of forest, of buildings	Local extent of sheltering
1	2	3	4	5	6
Yaroslavl' Oblast					
Gayutino.....	122	10	X Лс	3Л,	I
Ponshkhon'ye-Volodarsk.	109	16	Лс	3Л,	II
Mys Rozhnovskiy.....	103	17	Лс	3Л	I
Danilov.....	155	12	X Лс	3Л	I
Rybinsk, G.O.....	104	14	Лс	3Л,	II
Tutayev.....	125	13	X Лс	3Л	I
Yaroslavl', M.S.O.....	98	12	Лс	3Л,	I
Uglich.....	120	11	Лс	3Л,	II
Postov.....	99	14	Лс	—	II
Pereyaslavli'-Zaleskiy	174	13	X Лс	3Л	II
Kalinin Oblast					
Kes'ma.....	194	11	X Лс	3Л,	II
Bologoye.....	187	11	X Лс Б	3Л,	II
Maksatikhin.....	134	12	Лс Б	3Л,	II
Bezhetak.....	140	11	X Лс	—	I
Vyakhniy Volochek.....	167	12	Лс Б	3С,	II
Tolmach.....	138	12	X Лс Б	3Л,	II
Kashin.....	134	12	X Лс Б	3Л,	II
Ostashevskiy.....	217	11	X Лс Б	3Л	II
Kuvshinovskiy.....	252	11	X Лс Б	3Л	II
Torzhok.....	171	11	X Лс	3Л,	I
Sevelovo.....	122	12	X Лс Б	3Л	II
Staritsa.....	179	12	X Лс	3Л	II
Toropets.....	187	11	X Лс	3Л	II
Zapadnaya Dvina.....	200	12	X Лс Б	3Л	II
Belyy.....	212	11	X Лс Б	3Л,	I
Moscow Oblast					
Elin.....	166	11	X Лс	3Л,	I
Dmitrov.....	183	11	X Лс	3С,	II
Volokolamsk.....	187	11	X Лс	3Л	II
Pochinki.....	137	13	Лс Б	3Л,	I
Movo-Iyerusalim.....	159	11	X Лс	3Л,	I
Losinoostrovskaya.....	147	20	П	3С,	III
Moskva-S.-M. akademiya	162	26	П	3С,	II
Moskva, G.O.....	124	12	П	3С,	III
Kurovskoye.....	122	11	Лс	3Л,	II
Cherusti.....	127	11	Лс Б	3Л	II
Lobnyy.....	184	11	X Лс	3Л	II
Naro-Fominsk.....	166	11	X Лс Б	3Л,	II
Zolotarevskiy.....	112	12	Лс	3С	II
Mikhnerovo.....	178	17	Лс	3Л,	II
Serpukhov.....	163	12	X Лс	3Л	II
Yashino.....	219	11	X Лс	3Л	I

Water basin			Relief		Type of location by temperature	year	$\frac{v_{11}}{v_1}$	July	Remarks
Type	Form of shore line	Heading in relation to basin	Form of relief	Orientation					
7	8	9	10	11	12	13	14	15	
Yaroslavl' Oblast									
Jeyutino.....	O <sub>2</sub>	—	NE	P	—	—	4.4	1.5	At 8 km from center of city
Poshekhon'ye-Volodarsk.	O <sub>2</sub>	—	E	H	W	—	3.3	3.1	
ys Rozhnovskiy.....	O <sub>3</sub>	M	S - W	H	—	B	5.8	0.9	
Danilov.....	—	—	—	B <sub>1</sub>	—	—	4.1	2.1	
Rybinsk, G.D.....	O <sub>2</sub>	3	SE	H	—	—	4.4	1.7	
Rutayev.....	P <sub>1</sub>	—	NE	P	—	—	4.0	2.5	
Yaroslavl', ACS.....	—	—	—	P	—	—	4.5	2.1	
Uglich.....	O <sub>2</sub>	—	E, NE	P	—	B	3.7	1.9	
Postov.....	O <sub>2</sub>	—	NW	K	—	B3	3.3	2.0	
Pereyaslov'-Zalesskiy	O <sub>2</sub>	—	SE	XC <sub>1</sub>	—	—	3.8	1.7	
Kalinin Oblast									
Kes'na.....	—	—	—	C	S	—	3.9	2.4	In village, surrounded by forest on all sides No woods within radius of 25 - 30 km
Bologoye.....	—	—	—	P	—	—	3.5	2.6	
Makstikha.....	—	—	—	P	—	—	2.5	2.9	
Bezhetak.....	—	—	—	P	—	—	3.9	2.0	
Vyshniy Volochek.....	O <sub>2</sub>	—	E	P	—	B	3.6	2.1	
Tolmachi.....	—	—	—	B	—	—	3.6	2.3	
Kashin.....	—	—	—	P	—	—	3.5	2.3	
Yegor'lov.....	O <sub>2</sub>	—	SSE	H	—	C, B	3.9	1.8	
Kuvshinov.....	—	—	—	X	—	—	3.7	3.2	
Torzhok.....	—	—	—	B	—	—	4.2	2.1	
Savelovo.....	P <sub>1</sub>	—	E	P	—	—	3.2	2.3	On an elevation in the form of a ridge
Itaritsa.....	—	—	—	H <sub>1</sub> C	NE, W	—	4.0	2.1	
Chropets.....	O <sub>2</sub>	—	NW	B	—	—	3.4	2.2	
Lepadnaya Dvina.....	—	—	—	X	—	—	3.6	2.4	
Balyi.....	—	—	—	X, C	W	—	3.9	2.4	
Moscow Oblast									
Elin.....	—	—	—	X, C	N	—	3.8	2.7	In forest glade
Dmitrov.....	—	—	—	X, C	N	—	3.6	2.2	
Volokolamsk.....	—	—	—	X, C	NE	T	3.7	2.5	
Pechinki.....	—	—	—	P	—	—	3.5	3.3	
Novo-Iyerusalim.....	—	—	—	K	—	3	3.2	3.3	
Mosinoostrovskaya.....	—	—	—	P	—	—	3.3	3.0	
Moskva-S.-M. Andreyevskiy	—	—	—	P	—	—	3.6	2.2	
Moskva, G.D.....	—	—	—	P	—	—	2.7	1.8	
Kurovskoye.....	—	—	—	P	—	—	3.2	2.3	
Cherust.....	—	—	—	H	—	C	3.1	2.7	
Moskva.....	—	—	—	X, C	—	—	3.5	2.6	On high shore of Oka River, at 2 km
Yaro-Podinsk.....	—	—	—	K	—	3	3.2	3.7	
Meloma.....	—	—	—	P	—	—	3.1	2.3	
Mikheev.....	—	—	—	P	—	—	3.7	2.7	
Serpukhov.....	—	—	—	P	—	—	3.4	2.6	
Moskva.....	—	—	—	B	—	—	4.3	1.9	

Station	Height of lo- cation (m)	Wind rose Height (m)	Macro-roughness		
			General (land- scape)	Density of forest, of build- ings	Local extent of sheltering
1	2	3	4	5	7

Vladimir Oblast

Yur'yev-Pol'skiy.....	152	11	X A/c	3/7	II
Aleksandrov.....	185	11	X A/c	3/7	I
Gorokhovets.....	78	12	A/c B	3/7	II
Vladimir, G.B.....	168	12	II	3/7	II
Selivanovskoye Experi- mental Field.....	128	13	A/c	3/7	I
Petushki.....	147	11	X A/c B	3/7	I

Smolensk Oblast

Svetlova.....	280	11	X A/c	3/7	I
Velizh.....	185	11	X A/c B	3/7	I
Ozharok.....	194	9	X A/c	3/7	I
Novo-Prachistoyal.....	244	12	A/c	3/7	I
Leskov.....	185	11	A/c B	3/7	I
Yasn'ye.....	223	12	X A/c	3/7	I
Safonovo.....	214	11	X A/c	3/7	II
Pavino.....	282	11	A/c	3/7	I
Radiya.....	188	11	X A/c	3/7	I
Smolensk, A.M.C.....	223	11	A/c	3/7	I
Yel'nya.....	222	11	A/c	3/7	I
Pochinok.....	286	13	A/c	3/7	I

Kaluga Oblast

Maloyaroslavets.....	193	11	X A/c B	3/7	II
Konstant'insk.....	223	12	X A/c	3/7	I
Spas-Demensk.....	237	10	X A/c B	3/7	II
Sudzhichi.....	237	10	X A/c	3/7	II
Zhizdra.....	193	14	X A/c	3/7	II

Ryazan' Oblast

Tuma.....	122	13	A/c B	3/7	II
Yelat'ina.....	132	11	A/c B	3/7	II
Ryazan'.....	156	11	X A/c	3/7	II
Sasovo.....	114	12	A/c	3/7	II
Shilovo.....	98	11	A/c	3/7	I
Sterozhilovo.....	149	11	A/c	3/7	I
Shatak.....	121	10	A/c	3/7	I
Pavelets.....	229	13	X A/c	—	I
Ryazhsk.....	125	11	X A/c	—	I

Water Basin			Relief		Type	Year	July	Remarks
Type	Form of shoreline	Head- ing in relation to basin	Form & Δh	Orienta- tion	of loca- tion by temp- erature			
7	8	9	10	11	12	13	14	15

## Vladimir Oblast

Yur'yev-Pol'skiy.....	-	-	-	L C	E	-	3.8	2.5	On plateau of low hill
Aleksandrov.....	-	-	-	P	-	-	4.1	2.5	
Gorokhovets.....	-	-	-	H	-	-	3.2	2.7	
Vladimir, G.B.....	-	-	-	A	-	-	3.4	1.7	Wide forest glade
Selivonovskoye Experi- mental Field.....	-	-	-	P	-	-	3.1	3.2	
Potushki.....	-	-	-	L C	NW	-	3.2	2.4	Lower part of val- ley slope

## Smolensk Oblast

Sychovka.....	-	-	-	P	-	-	3.9	1.8	
Velizh.....	-	-	-	P	-	-	4.0	2.5	
Gzhatok.....	-	-	-	P	-	-	2.3	2.9	
Novo-Predistoyel....	-	-	-	P	-	-	4.1	1.9	
Dudov.....	-	-	-	P	-	-	4.1	2.6	
Vysokaya.....	-	-	-	P	-	-	3.9	2.3	
Safonovo.....	-	-	-	P	-	-	3.7	2.9	
Tekino.....	-	-	-	L C	SE, W	-	3.6	2.6	
Rudnya.....	-	-	-	P	-	-	3.7	2.3	
Smolensk, RSC.....	-	-	-	C	SW	-	3.0	2.0	
Yel'nya.....	-	-	-	P	-	-	4.5	2.3	
Pochinok.....	-	-	-	P	-	-	4.0	2.3	

## Kaluga Oblast

Maloyaroslavets.....	-	-	-	P	-	-	3.2	2.4	
Kosel'sk.....	-	-	-	P	-	-	4.1	2.2	
Snas-Doroginsk.....	-	-	-	P	-	-	3.8	2.2	
Yatynitski.....	-	-	-	L C	SW, W	-	3.4	2.6	
Zhizdra.....	-	-	-	L C	E	-	3.3	2.9	

## Ryazan' Oblast

Yasnaya.....	-	-	-	H	-	-	3.7	2.0	In a slight depression
Velat'sk.....	-	-	-	P	-	3	3.6	2.3	
Shchegolev.....	-	-	-	P	-	-	4.9	2.2	
Shchegolev.....	-	-	-	P	ACs	C 3	4.4	2.2	
Shilovo.....	-	-	-	P	-	-	4.0	2.0	
Staroshilovo.....	-	-	-	P	-	-	4.2	2.1	
Kharkov.....	-	-	-	P	-	-	4.3	2.3	
Kharkov.....	-	-	-	P	-	-	3.3	1.9	
Kharkov.....	-	-	-	P	-	-	4.1	2.3	

# Conclusion of Supplement I

90-91

Station	Height of location (m)	Height of wind vane (m)	General (land-scope)		Density of forest of buildings		Extent of local sheltering	Form of shoreline		Relief	Type of station	Type of station by season	Remarks
			4	5	6	7	8	9	10				
1	2	3	4	5	6	7	8	9	10	11	12	13	14

Tula (Tul'skaya) Oblast

Tula.....	165	11	I, II	30	11	11	11	11	11	11	11	11	11
Volovo.....	200	14	I, II	30	11	11	11	11	11	11	11	11	11
Chern' & Surovovo...	245	11	I, II	11	11	11	11	11	11	11	11	11	11

Tula Oblast

Remarks. To column 4: X - hilly relief, 7c - mixed forest, 7n - deciduous forest, 7C - forest-steppe, 7I - industrial region, city.

To column 6: I - open, individual structures and trees; II - among buildings, trees, not towering over the wind vane (anemometer); III - among multi-story buildings, trees towering above vane.

To column 7: 0 - lake; P - river. The exponent at the conventional notation of the type of water basin indicates the point rating of the basin's size (at river - the cross section; at a lake - the area; point (force) 1 is dropped).

## Cross Section of River (km)

Area of Lake or Reservoir (km <sup>2</sup> )	Point
0.5-1	1
1-2	2
>2	3

The subscript, at the conventional notation of the basin's type, characterizes in points the distance to it (point 1 is omitted).

## Distance (km)

Points
<0.5
0.5-2
1
2

To column 9. In this column, it is noted on what shore of the basin the station is situated, i.e. the orientation of the shore by compass points is given. If the station is located on a cape, all the directions are indicated along which the distance to the basin is less than 2 km.

To column 10. P - plains,  $\nabla$  - valley, H - lowland, C - slope, B - peak, X - hill,  $\nabla_n$  - straight valley (oriented in the direction of the prevailing wind), K - trough. For the slope, the subscript S indicates top, center (no notation), " - bottom. For example, C<sub>S</sub> signifies the "upper part of slope". The exponent at the conventional symbol of the relief form indicates the difference in heights ( $\Delta h$ ) in the following point system of evaluation:

Difference in height (m)	Points
< 50	1 (is omitted)
50 - 200	2
200 - 750	3
750 - 1500	4
> 1500	5

To column 11. The orientation is indicated by 16 compass points. For the valleys, the downstream direction is given. In the case of complex relief, the orientation of all the relief components is indicated. The orientation is not given for the peaks and hills.

To column 12. 3 - negative relief forms (valleys, troughs, saucer-shaped depressions, and also the vegetation and glades favoring the stagnation of air, where the wind speed has slackened). T - positive relief forms (peaks of mountains, hills etc.) with favorable conditions for turbulent air mixing (the wind has freshened). C = moist, marshy areas. B - near a large water body (rivers, lakes, not farther than 1 - 1.5 km).  $\nabla$  - city, industrial region.

## LIST OF STATIONS OF AEROLOGICAL OBSERVATIONS

Name of Station	Height	Height above sea level	Period of observations (year)
Leningrad.....	12	72	1959-1963
Vologda.....	—	117	1928-1934; 1936-1952
Kirov.....	17	164	1959-1963
Riga.....	13	14	1959-1963
Vellidye Iud.....	—	100	1934, 1936, 1939, 1940, 1947-1952
Bologoye.....	—	180	1928-1932, 1938-1940, 1947-1952
Moscow.....	12	157	1938-1952, 1959-1963
Gor'kiy.....	—	160	1928-1934, 1936, 1938, 1939, 1941, 1943, 1945-1952
Kazan'.....	11.5	120	1959-1963
Kaunas.....	27	86	1959-1963
Minsk.....	16	225	1959-1963
Smolensk.....	—	243	1934-1940, 1944-1952
Orel.....	—	190	1937-1941, 1945-1952
Kuybyshev.....	13.5	45	1959-1963
L'vov.....	12	329	1959-1963
Kiev.....	10	166	1959-1963
Khar'kov.....	13	147	1959-1963
Volgograd.....	10	141	1959-1963
Astrakhan.....	11	-24	1959-1963
Aleksandrovs'koye.....	13	47	1959-1963
Barabinsk.....	10	120	1959-1963
Taragunda.....	10	548	1959-1963
Krasnovodsk.....	12	90	1959-1963
Tashkuz.....	11	88	1959-1963

DIURNAL VARIATION OF WIND SPEED IN THE ATMOSPHERIC PLANETARY  
BOUNDARY LAYER

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Institute of Aeroclimatology. Transactions)  
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The climatological studies of the diurnal wind pattern in the boundary layer are made more difficult by the limited number of the observation periods. As is known, in the network of the aerological stations, the radio-wind sounding of the atmosphere is conducted two, three or in the best case, four times per 24 hours. However, even based on the results of a quadruple sounding, it is difficult to establish the position of the typical points necessary for constructing the reliable curves of the diurnal variations in the wind at various heights.

Obviously, any given period of sounding can not be equally representative for the entire depth of a boundary layer. For example, if the observations at 1300-1400 hours characterize the diurnal maximum of wind speed at the Earth's surface, this does not signify that these observations are to some extent indicative also for the height of 300, 500 or 1,000 m. With the same justification, we can state that any given combination of several observations periods, being representative for some heights, will prove unconditionally nonrepresentative for the others. Therefore, it is necessary to have such a number of observation periods, which in combination would permit us to obtain sufficient data for an objective description of the diurnal wind pattern at all heights, i.e. from the Earth's surface to the upper limit of the boundary layer.

In an ideal case, this number should be 24, since only an hourly sounding of the atmosphere is capable of providing exhaustive data for a detailed investigation of the diurnal pattern of the wind speed. However, such a frequency of sounding can be realistic only in the form of individual discontinuous

series at separate observation points. Therefore, the available data of hourly soundings are so limited that their utilization for climatological purposes is practically impossible.

In connection with what has been indicated, it appears feasible to utilize the results of the quadruple radio-wind sounding in combination with the data of pilot-balloon observations. Such combined aerological observations--radio-wind observations in the basic periods and the pilot-balloon observations in the intermediate periods are conducted during a number of years at a considerable number of stations in the airports. In this connection, we have in mind the pilot-balloon observations taken from one point, since now, the regular basic observations are not conducted anywhere.

It is understandable that the combined utilization of the direct results of the pilot-balloon and radio-wind observations is impossible, since the difference in the methods of deriving these results cause their dissimilarity. Therefore, the reduction of the pilot-balloon and radio-wind data to a single sounding method is required. /99

Although in a study of the lower atmospheric layers, the pilot balloon observations have certain advantages over the radio-wind observations [18]; at the present time, the latter are the principal and most popular method of measuring the wind aloft. Moreover, the radio-wind observations are distinguished by great regularity, as a result of which their results do not suffer from that selectivity which unfortunately is typical for the data collected from the pilot balloon observations [24]. Obviously, with consideration of this circumstance, it is feasible to reduce the results of the pilot balloon observations to the data taken from the radio-wind sounding, and not vice versa.

For reducing the pilot balloon observations to the radio-wind ones, it is necessary to know the errors in the first relative to the second. Obviously, the more reliable and objective technique of detecting such errors can be a comparison of the results of the observations conducted simultaneously by the radio-wind and pilot balloon methods. Applying this method, the radio-wind and pilot balloon observations are usually conducted for the flight of the same balloon; we compare the results of the observations obtained by both methods for the same heights. However, such observations are conducted only spasmodically, as a result of which their utilization for climatological purposes, including for reducing a series of observations to one sounding method, is extremely difficult. In connection with this, the indicated reduction is achieved by us in a different way, specifically: by the method of differences in the many years' values of the average diurnal wind speeds.

The basis for the application of this method has been provided by the assumption that the mean diurnal values of a meteorological element can be derived based on the observation data in any four periods equidistant from each other. As the experience in processing the many years' observations indicates, this assumption is sufficiently reliable in respect to the average wind speed values. Hence, if the radio-wind and pilot balloon observations did not contain errors, or their errors were the same, in the problem which we are solving, the mean diurnal values of wind speed computed separately based on the data of one or the other observations, should also be identical. However, in reality, such a coincidence does not exist, and this is evidence of the dissimilarity of the data from the pilot balloon and radio-wind observations, which needs to be eliminated.

The gist of the method is as follows. For the same fixed heights, we calculate the many years' mean diurnal values of wind speed separately based on the data for four equidistant periods of radio-wind sounding ( $\bar{v}_{rn}$ ) and for four other equidistant periods, in which the pilot balloon observations were conducted ( $\bar{v}_{pn}$ ). Then, we take the difference in these values:

$$\Delta v = \bar{v}_{rn} - \bar{v}_{pn} \quad (1)$$

representing the error in the pilot balloon observations relative to the radio-wind observations (with opposite sign).

If we assume that the difference  $\Delta \bar{v}$  is stable for all the periods, the average speed value for the given period, obtained from the many years' pilot balloon observations, can be reduced to the value  $\bar{v}_{rp}$  of the adequate "average radio-wind" for this same period, specifically:

$$\bar{v}_{rp} = \bar{v}_{pn} + \Delta \bar{v} \quad (2) \quad /100$$

In spite of the obvious simplicity of the method described, its application permits us first to exclude the effect of the actual instrumental errors of the pilot balloon observations for the average characteristics of wind speed, and secondly to suppress to a considerable extent the dependence of these characteristics upon the selective property of the pilot balloon data. As regards the effect of the systematic errors of the radio-wind sounding, it is naturally retained, also extending in the given instance to the pilot balloon observations. However, with a proper installation and skillful operation of the equipment used in the radio-wind sounding, these errors are

close to zero [3, 8, 10], and for practical purposes are not reflected on the averaged values of wind speed [8, 22]; we will not discuss them (we will discuss below the accuracy of the many years' average data, obtained from the actual statistical compilation utilized by us).

Table 1

Many Years' Average Diurnal Wind Speed ( $\bar{v}$  m/sec) in Various Months Based on Radio-Wind Sounding Data & Pilot Balloon Observations (n=no. of terms in series)

Month	Height (m)									
	Wind vane		300		600		850		1350	
	$\bar{v}$	n	$\bar{v}$	n	$\bar{v}$	n	$\bar{v}$	n	$\bar{v}$	n
Radio wind observations										
January...	620	4.3	316	8.8	301	9.4	497	9.5	487	9.6
February...	564	3.0	467	8.3	441	9.0	439	9.5	487	9.6
March...	620	3.1	320	8.8	498	9.2	523	9.5	513	9.3
April...	600	4.7	549	8.3	542	8.5	550	8.7	551	8.8
May...	620	4.6	503	7.7	569	8.1	545	8.3	537	8.2
June...	600	3.6	583	6.7	575	6.8	567	7.1	563	7.2
July...	620	8.7	602	7.1	601	7.7	592	7.4	588	7.3
August...	620	3.6	597	7.3	595	7.4	597	7.7	597	7.5
September...	608	3.6	596	8.0	583	8.3	563	8.2	566	8.4
October...	619	4.0	407	8.8	553	9.2	585	9.2	584	9.1
November...	609	4.6	578	9.1	564	9.9	557	9.6	546	9.3
December...	619	4.5	596	8.9	584	9.5	585	9.5	573	9.5
Pilot balloon observations										
January...	619	4.3	315	8.1	291	8.8	289	8.8	164	—
February...	564	3.1	346	7.4	220	8.6	194	—	163	—
March...	620	3.2	455	7.7	353	8.7	296	9.1	255	9.2
April...	600	4.9	518	7.4	480	7.9	431	8.1	376	8.7
May...	618	4.6	393	6.9	562	7.2	534	7.3	491	7.5
June...	599	3.7	382	6.3	374	6.3	356	6.4	340	6.7
July...	620	3.9	602	6.4	394	6.4	375	6.4	347	6.8
August...	620	3.8	396	6.6	371	6.8	351	7.0	303	7.3
September...	599	3.7	566	6.6	339	7.0	310	7.2	451	7.8
October...	620	2.9	336	7.4	484	8.5	430	8.8	357	8.2
November...	600	4.5	332	8.3	244	9.2	195	—	162	—
December...	610	4.4	315	8.0	220	8.6	184	—	166	—

\*At inadequate number of initial data (less than 200), mean wind speed was not computed.

In a study of the diurnal pattern of wind speeds in the boundary layer, we had the opportunity of utilizing the results of the radio-wind sounding in Kharkov at 0300, 0900, 1500, 2100 hours and of the pilot balloon observations at 0000, 0600, 1200, and 1800 hours Moscow Standard Time, or respectively around 0200, 0800, 1400, 2000 hours, and 0500, 1100, 1700, and 2300 hours mean solar time for the five year period from 1959 to 1963.

In Table 1, we have listed the many years' values of the mean diurnal wind speeds for certain levels above the Earth's surface (approximately every 300-500 m), calculated for each month based on the results of the radio-wind sounding, pilot balloon observations and observations with a wind vane (anemometer). It is obvious from this table that the mean diurnal values of the wind speed according to the anemometer calculated according to the data for the various periods, are practically identical. Consequently, the judgment expressed earlier relative to the coincidence of the mean diurnal wind speed values, obtained based on the data of the standardized observations for any four equidistant periods, finds excellent confirmation here.

At the same time, an analysis of the data listed in Table 1 indicates that the mean diurnal values of wind speed, calculated separately based on the results of the radio wind sounding and of the pilot observations, are significantly different; moreover, these differences are always identical in sign and in general are fairly close to each other in absolute value.

A more graphic illustration of what has been stated above is given in the data in Table 2, in which we have tabulated the differences  $\Delta \bar{v}$ , obtained according to Eq. (1).

In Table 3, compiled similarly to the first two, but containing the many years' data in a seasonal average, there is depicted quite distinctly one of the significant features in the indicated difference. This feature consists in a significant reduction in the values of  $\bar{v}$  with height. Obviously, the latter is associated with the reduction, in the same direction, of the deviations in the actual vertical velocity of pilot balloons from the calculated velocity.

Table 2

Difference  $\Delta_v$  (m/sec) of Many Years' Values of Mean Diurnal Wind Speed Calculated Separately Based on the Data of the Radio Wind Sounding and the Pilot Balloon Observations

Month	Wind value	Height (m)			
		300	600	900	1200
January.....	0.0	0.3	0.6	0.7	—
February.....	-0.1	0.3	0.4	—	—
March.....	-0.1	1.1	0.5	0.4	0.1
April.....	-0.2	2.9	0.7	0.6	0.1
May.....	0.0	0.6	0.9	1.0	0.7
June.....	-0.1	0.4	0.5	0.7	0.3
July.....	-0.2	2.7	0.8	1.0	0.5
August.....	-0.2	0.7	0.6	0.7	0.3
September.....	-0.1	1.4	1.3	1.0	0.6
October.....	0.1	1.4	0.7	0.4	0.3
November.....	0.1	0.9	0.7	—	—
December.....	0.1	0.9	0.9	—	—

\*Refer to remark to Table 1.

It is known that a well-developed turbulent mixing decreases the resistance exerted upon a pilot balloon during its descent. As a result of this, the actual vertical velocity of the balloon is usually greater than the calculated one, according to which we establish the height of the pilot balloon which is observed from one point. Thus, based on the many years' observations conducted in Slutsk (Pavlovsk), Molchanov [19] detected in the lower layers appreciable positive deviations in the vertical velocity of the pilot balloons from the theoretically calculated velocity ( $\Delta_w$ ). Decreasing with height, the deviations in  $\Delta_w$  attain at the 2 km level the zero values. Analogous results were obtained in the investigations conducted by Pinus [12], in the Borispol'e region ([Note]: The positive deviations in  $\Delta_w$  are typical chiefly for the plains localities. As the studies conducted by the Main Geophysical Observatory under the supervision of P. A. Vorontsov and Ye. S. Selezneva [6] demonstrate, under mountain conditions, the  $\Delta_w$ -values can be negative in the layer from the surface of the Earth to a height of around several hundreds of meters. The same circumstance is recorded by T. N. Klado [14]. Evidently, the negative

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deviations in  $\Delta_w$  are associated with the katabatic movements of air near the mountain passes [25].

Table 3

Many Years' Mean Diurnal Wind Speed ( $\bar{v}$  m/sec) in Various Seasons \*  
(n = number of terms in the series)

Season	Height (m)									
	W. value		300		600		850		1300	
	n	$\bar{v}$	n	$\bar{v}$	n	$\bar{v}$	n	$\bar{v}$	n	$\bar{v}$
Radio Wind Sounding										
Spring.....	1840	4.8	1634	8.2	1889	8.6	1618	8.9	1873	8.6
Summer.....	1840	3.6	1784	7.8	1776	7.2	1751	7.4	1740	7.4
Fall.....	1819	4.1	1771	8.8	1745	9.1	1715	9.8	1826	9.9
Winter.....	1893	4.7	1579	8.7	1538	9.4	1629	9.5	1612	9.6
Pilot-Balloon Observations										
Spring.....	1538	4.8	1585	7.3	1587	7.8	1761	8.8	1125	8.2
Summer.....	1539	3.8	1739	6.4	1749	6.5	1682	6.6	1560	6.9
Fall.....	1819	4.1	1434	7.3	1287	8.8	1135	8.2	977	8.5
Winter.....	1882	4.7	978	7.8	701	8.7	578	8.8	485	-*
Difference $\Delta$ :										
Spring.....		-0.1		0.9		0.8		0.9		0.4
Summer.....		-0.3		0.6		0.7		0.8		0.5
Fall.....		0.0		1.3		1.1		0.8		0.4
Winter.....		0.0		0.9		0.7		0.7		-

\* Average value of velocity was not computed owing to an insufficient amount of raw data (less than 500).

Since the calculated vertical velocity during the turbulent mixing is less than the actual velocity, the determination of the wind speed based on the depressed vertical velocity causes a lowering in the values of the wind speed. It is specifically this condition which leads to the formation of systematic positive differences between the wind speed values collected by the radio wind and pilot balloon methods. With height, the value of deviation in  $\Delta_w$  decreases; therefore, we can naturally expect that in this same direction, the  $\Delta \bar{v}$ -values will also decrease. However, under the influence of certain other factors (the increase or decrease in wind speed with height, the greater or lesser selectivity of the pilot balloon data, and so forth), the variation in  $\Delta \bar{v}$  does not always take place uniformly.

Sometimes, especially in summer, the reduction in the value for  $\Delta \bar{v}$  generally does not occur in the lower kilometer layer.

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In the annual pattern, the maximum for  $\Delta \bar{v}$  falls in spring or autumn, when the relatively high wind speeds accompany a considerable turbulent mixing. In summer, the minimal values of  $\Delta \bar{v}$  can be explained by the low wind speeds, while in winter, they can be explained by the decreased turbulent exchange of air. Similarly to this, there should also take place a certain difference between the  $\Delta \bar{v}$ -values in their diurnal pattern. Unfortunately, the method employed by us does not permit us to calculate with sufficient reliability the contribution of each individual period of observations in the formation of the average diurnal value for  $\Delta \bar{v}$ . However, we can assume that the diurnal fluctuations in  $\Delta \bar{v}$  are not so appreciable that they are perceptibly reflected on the results of the analysis of the diurnal wind speed pattern based on the averaged data. In particular, for such an assumption there is the substantiation that above 100 m, the intensification of the turbulent exchange (mixing) as a rule is accompanied by a decrease in wind speed and contrariwise (the opposite diurnal pattern of intensity of turbulent mixing and wind speed should probably exert a compensating effect upon the variation in the  $\Delta \bar{v}$ -values during a 24-hour period). Nevertheless, admitting in our calculations the independence of the  $\Delta \bar{v}$ -values upon the observation periods, we calculate this value as reliable only in a first approximation.

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A further important feature of the difference  $\Delta \bar{v}$  consists in the fact that its values exist in a definite dependence on the nature and degree of the selectivity of the data obtained by the pilot balloon observations. Owing to this, being utilized as a correction to the average values of wind speed acquired based on the pilot balloon data,  $\Delta \bar{v}$  permits us to suppress to some extent or other their selective property. In reality, if the selectivity of the pilot balloon observations is manifested in such a way that the value for the mean diurnal wind speed proves to be lowered,  $\Delta \bar{v}$  correspondingly increases, and its corrected value becomes close to the actual one. However, certain difficulties can develop if the extent and particularly nature of the selectivity of the observations change systematically from some periods to others. Under the assumption of such variations, it is often necessary to revert to an analysis of the original data, and in case of their insufficiency (see the lines drawn in Tables 1-3) in general we omit the calculation of  $\Delta \bar{v}$ .

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Table 4

Many Years' Average Wind Speed (m/sec) Based on the Pilot Balloon Data: Original ( $\bar{V}_{\text{псн}}$ ) and Reduced to the Radio-Theodolite Method of Observations ( $\bar{V}_{\text{нр}}$ ). Autumn.

Wind speed	Time (hours)			
	05	11	17	23
300 m				
$\bar{V}_{\text{псн}}$	7.7	6.4	7.2	8.0
$\bar{V}_{\text{нр}}$	1.3	1.3	1.3	1.3
$\Delta \bar{V}$	9.3	7.7	8.5	9.3
600 m				
$\bar{V}_{\text{псн}}$	8.2	7.8	7.9	8.2
$\bar{V}_{\text{нр}}$	1.1	1.1	1.1	1.1
$\Delta \bar{V}$	9.3	8.9	9.8	9.3
900 m				
$\bar{V}_{\text{псн}}$	8.3	8.4	8.1	8.0
$\bar{V}_{\text{нр}}$	0.8	0.8	0.8	0.8
$\Delta \bar{V}$	9.1	9.2	8.9	8.8
1200 m				
$\bar{V}_{\text{псн}}$	8.5	8.6	8.4	8.4
$\bar{V}_{\text{нр}}$	0.4	0.4	0.4	0.4
$\Delta \bar{V}$	9.0	9.0	9.2	9.2

In this manner, the difference  $\Delta \bar{V}$  has two main sources: the deviation of the actual vertical velocity of the pilot balloon from the calculated velocity ( $\Delta_w$ ) and the selective quality of the pilot balloon observations. The relative contribution of these sources to the formation of each actual value of  $\Delta \bar{V}$  can be various, however generally the principal role obviously belongs to the deviations in  $\Delta_w$ .

The typical case of reducing the averaged data of the pilot balloon observations to the radio wind method of sounding is presented in Table 4 (the  $\Delta \bar{V}$ -values are taken from Table 3).

In Table 5, placed at the basis of a series of further constructions, we have presented the many years' average wind speeds calculated from the results of the radio wind sounding, while for the part of the specific heights--based on the data presented from the pilot balloon observations. The content of

this table confirms well the existing general concepts concerning the nature of the diurnal pattern of the wind speed in the boundary layer and moreover permits us to form a concrete judgment concerning the quantitative aspect of the object of the present investigation. However, the data presented in Table 5 do not provide a sufficiently graphic pattern of the variations in wind speed during a 24-hour period.

Table 5

Many Years' Average Wind Speed (m/sec) at Various Times of Day

Height (m)	Time (hours)								Days
	02	05	08	11	14	17	20	23	
Spring									
Wind vane	3.9	4.0	4.3	3.9	4.0	5.6	4.3	4.3	4.9
100	7.0		6.8		7.5		7.4		7.2
200	6.3		7.5		7.6		8.4		7.9
300	6.5	6.8	7.8	7.2	7.6	7.3	8.8	9.4	8.2
400	6.7	9.0	8.5	8.0	8.0	8.0	9.0	9.5	8.6
500	6.8	9.0	9.1	8.5	8.4	8.2	9.1	9.4	8.8
1200	6.5	8.8	9.2	8.7	8.5	8.2	8.6	9.0	8.7
1800	6.7		9.6		8.7		8.5		8.8
Summer									
Wind vane	2.4	2.5	2.6	3.0	3.1	4.8	3.1	2.8	3.7
100	6.5		5.3		6.6		6.3		6.2
200	7.4		5.8		6.7		7.2		6.6
300	7.6	7.4	6.1	6.1	6.7	6.5	7.6	8.0	7.0
400	7.4	7.4	7.0	6.6	6.6	7.1	7.7	7.8	7.2
500	7.2	7.5	7.3	6.3	7.1	7.6	7.8	7.8	7.4
1200	7.1	7.8	7.9	7.1	7.1	7.2	7.6	7.5	7.4
1800	7.7		7.9		7.5		7.6		7.7
Fall									
Wind vane	2.5	2.5	2.9	3.0	3.1	4.2	3.8	3.6	4.1
100	7.0		6.7		7.0		7.4		7.0
200	6.2		7.6		7.3		8.4		7.9
300	9.1	9.0	8.5	7.7	7.8	8.5	9.2	9.3	8.6
400	9.2	9.3	9.3	8.9	8.5	9.0	9.6	9.3	9.1
500	8.8	9.1	9.3	9.2	8.7	8.9	9.1	8.8	9.0
1200	8.8	9.0	9.2	9.0	8.8	8.8	9.0	8.8	8.9
1800	9.3		9.1		9.3		9.0		9.2
Winter									
Wind vane	4.4	4.5	4.5	4.9	5.0	4.7	4.6	4.5	4.6
100	6.9		7.1		6.9		7.3		7.0
200	6.1		8.0		7.8		8.3		8.0
300	8.6	9.0	8.9	8.6	8.2	8.5	8.9	8.8	8.7
400	9.2	9.6	9.5	9.3	9.3	9.4	9.4	9.3	9.4
500	9.5	9.8	9.5	9.7	9.5	9.2	9.6	9.4	9.5
1200	9.6		9.4		9.6		9.7		9.6
1800	9.6		9.4		10.0		9.8		9.8

These variations are portrayed more distinctly in Table 6, where we have shown the deviations  $\delta \bar{v}$  of many years' average wind speed values for each individual period of observations ( $\bar{v}_{av}$ ) from the many years' mean diurnal value of the speed ( $\bar{v}_{diur}$ ).

For each specific height, the indicated deviations are calculated according to the expression:

$$\delta \bar{v} = \bar{v}_p - \bar{v}_{dur} \quad (3)$$

(cp = av cpr = diurnal)

Table 6

Deviations  $\delta \bar{v}$  (m/sec) of Mean Values for Wind Speed at Various Times of Day ( $\bar{v}_{cp}$ ) from the Mean Diurnal Value of Speed ( $\bar{v}_{dur}$ )

Height (m)	Time (hours)							
	02	05	08	11	14	17	20	23
Spring								
Wind vane	-1.0	-0.9	-0.1	1.0	1.1	0.7	-0.4	-0.6
100	-0.2		-0.4		0.3		0.3	
200	0.3		-0.4		-0.3		0.3	
300	0.6	0.6	-0.4	-1.0	-0.6	-0.9	0.6	1.2
400	0.1	0.4	0.2	-0.6	-0.6	-0.6	0.4	0.9
500	0.0	0.2	0.3	-0.3	-0.4	-0.6	0.3	0.6
1200	-0.2	0.1	0.4	0.0	-0.2	-0.5	-0.1	0.3
1500	-0.2		0.6		-0.1		-0.2	
Summer								
Wind vane	-1.3	-1.2	-0.1	1.3	1.4	1.1	-0.6	-0.9
100	0.3		-0.9		0.4		0.1	
200	0.6		-1.0		-0.1		0.4	
300	0.6	0.4	-0.9	-0.9	-0.3	-0.5	0.6	1.0
400	0.2	0.2	-0.2	-0.6	-0.6	-0.1	0.5	0.6
500	-0.2	0.1	0.1	-0.5	-0.3	0.2	0.4	0.4
1200	-0.3	0.4	0.5	-0.3	-0.3	-0.2	0.2	0.1
1500	0.0		0.2		-0.2		-0.1	
Fall								
Wind vane	-0.6	-0.6	-0.2	0.9	1.0	0.1	-0.3	-0.5
100	0.0		-0.3		0.0		0.4	
200	0.3		-0.3		-0.6		0.5	
300	0.5	0.4	-0.1	-0.9	-0.8	-0.1	0.6	0.5
400	0.1	0.2	0.2	-0.2	-0.6	-0.1	0.5	0.2
500	-0.2	-0.1	0.3	0.2	-0.3	-0.1	0.1	-0.2
1200	-0.1	0.1	0.3	0.1	-0.1	-0.1	0.1	-0.1
1500	0.1		-0.1		0.1		-0.2	
Winter								
Wind vane	-0.2	-0.1	-0.1	0.3	0.4	0.1	0.0	-0.1
100	-0.1		0.1		-0.1		0.3	
200	0.1		0.0		-0.4		0.3	
300	0.1	0.3	0.2	-0.1	-0.3	-0.2	0.2	0.1
400	-0.2	0.2	0.1	-0.1	-0.1	-0.0	0.0	-0.1
500	0.0	0.3	0.0	0.2	0.0	-0.3	0.1	-0.1
1200	0.0		-0.2		0.0		0.1	
1500	0.0		-0.4		0.3		0.0	

The nature of the diurnal wind speed pattern can be represented particularly clearly by the isopleths of the deviations  $\delta \bar{v}$  in the height-time coordinates. Without professing to show a high accuracy of the reflection of diurnal speed variations in all the possible details, such isopleths (Fig. 1-4) permits us to detect easily the maximums (maximum possible deviations) and the minimums (maximum negative deviations) of wind speed during a 24-hour period, the difference in their values and the time of arrival at any given height. In addition, based on the interpolated values between the isopleths, with the aid of the equation

$$\bar{v}_{\text{max}} = \bar{v}_{\text{avr}} \pm \delta \bar{v} \quad (4)$$

it is easy to derive fairly reliable hourly values of wind speed ( $v_{\text{hour}}$ ) for each fixed height. It was just by such a method that we calculated the hourly values (Table 7), having served as a basis for constructing the isopleths of the many years' average wind speeds.

Proceeding to a review of the features of the diurnal pattern of wind speed, let us explain first of all how accurate the derived average values of speed are. Since as the basic data, we adopted here the data from the radio wind observations, it is very important that they correspond above all to the requirements of a reliable analysis.

As a measure of the accuracy of the many years' average speed values based on radio wind observations, we adopted the mean-square error:

$$\sigma_v = \frac{\sigma_v'}{\sqrt{n}} \quad (5)$$

where  $\sigma_v'$  = mean-square deviation in speed,  $n$  = number of terms in the series.

In Table 8, we have presented the results obtained from the calculation of  $\sigma_v'$ , which show that the errors of the many years' average monthly values of wind speed reach 0.2-0.3 m/sec for the level of 100 m and 0.3-0.4 m/sec for the level around 1,000 m.

It is obvious that such an accuracy of the average values can not be recognized as adequate for an analysis of the diurnal variations in the wind speed. In connection with this, in place of the average monthly values, we selected the data in a seasonal averaging, owing to which the error in the average values was cut in half. This permitted us to reveal the typical features of the diurnal wind speed pattern with an accuracy acceptable in the practice.

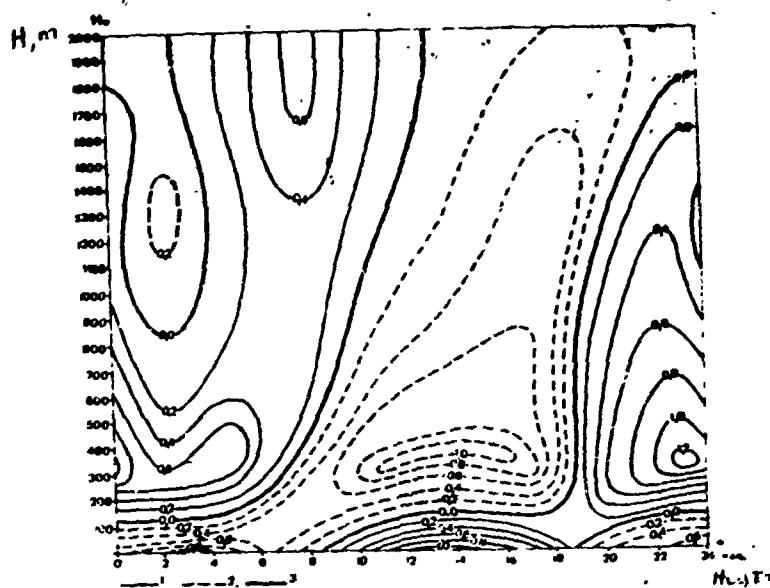


Fig. 1. Isopleths of Deviation in Average Wind Speed (m/sec) at Various Times of Day from the Mean Diurnal Value of Speed. Spring. 1- positive deviations, 2- negative, 3- zero.

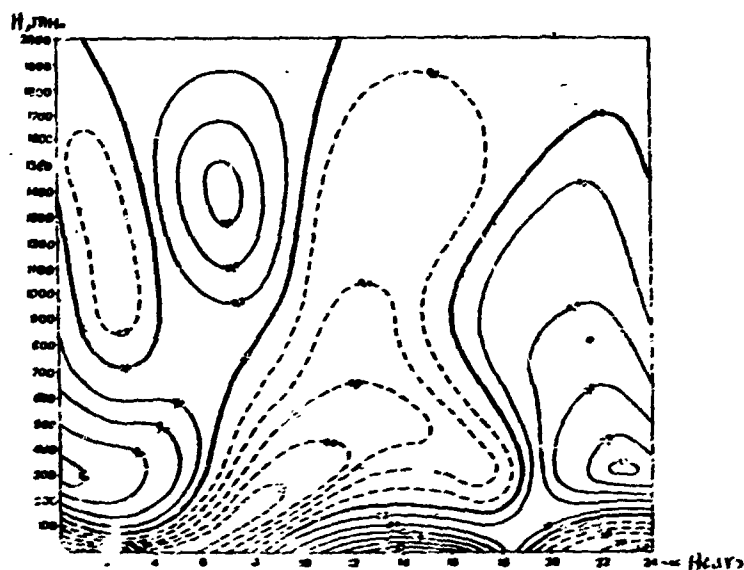


Fig. 2. Isopleths Indicating the Deviations in Average Wind Speed (m/sec) at Various Times of Day from the Mean Diurnal Value of Speed. Summer.

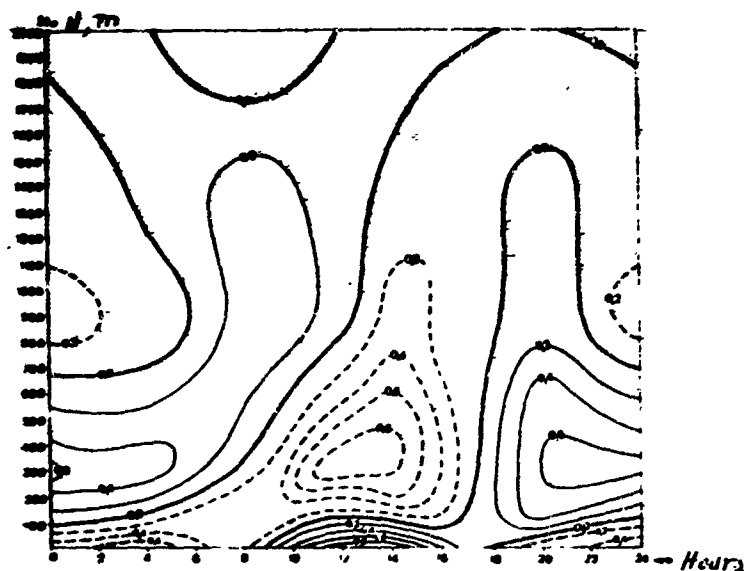


Fig. 3. Isopleths Indicating the Deviation in Average Wind Speed (m/sec) at Various Times of Day from the Mean Diurnal Value of Speed. Autumn.

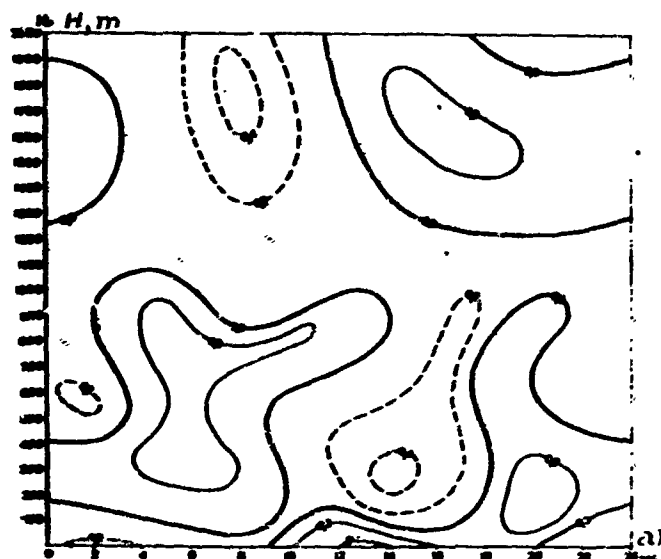


Fig. 4. Isopleths Indicating the Deviations in Average Wind Speed (m/sec) at Various Times of Day from the Mean Diurnal Wind Speed Value. Winter. Key: a) hours.

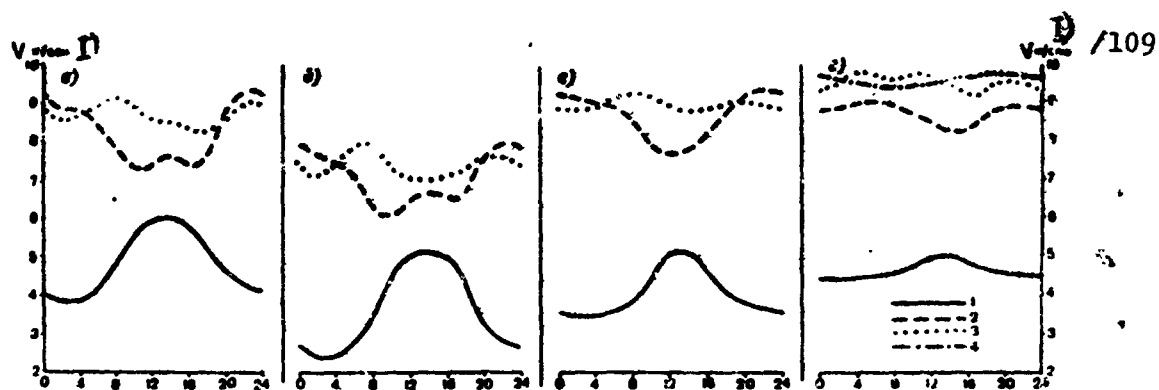


Fig. 5. Diurnal Wind Speed Pattern at Various Levels in Spring (a), Summer (b), Autumn (c) and Winter (d). 1- anemometer; 2- 300 m; 3- 1,350 m (for winter 850 m); and 4- 1,350 m (for winter). Key:  $I$ ) m/sec.

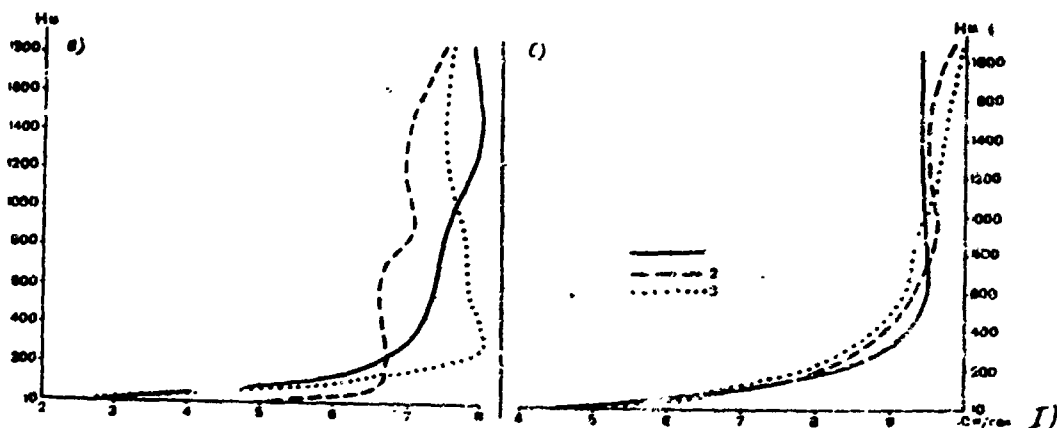


Fig. 6. Average Vertical Wind Profile at Various Times of Day in Summer (a) and in Winter (b). 1- 0600 hours in summer and 0800 hours in winter; 2- 1400 hours in summer and 1200 hours in winter; 3- 2300 hours in summer and 1600 hours in winter. Key:  $I$ ) m/sec.

Table 7

Many Years' Wind Speed (m/sec) for Each Hour of the Day, Average Diurnal ( $\bar{V}$  m/sec) Based on Hourly Values in Amplitude of Diurnal Fluctuations in Speed ( $A$  m/sec)

H, m	Time (hours)											
	0	1	2	3	4	5	6	7	8	9	10	11

Spring

Wind vane	4.1	4.0	3.9	3.9	3.9	4.0	4.2	4.5	4.8	5.1	5.5	5.9	5.9
100	7.0	7.0	7.0	7.0	6.9	6.8	6.7	6.7	6.8	7.0	7.1	7.3	7.4
200	5.3	5.3	5.2	5.2	5.1	5.0	4.8	4.5	4.5	4.4	4.4	4.5	4.6
300	5.2	5.0	4.8	4.8	4.8	4.8	4.5	4.2	4.3	4.6	4.4	4.2	4.4
600	5.1	5.0	4.7	4.8	4.9	5.0	5.0	4.9	4.8	4.6	4.3	4.0	4.0
850	5.2	5.0	4.8	4.8	4.9	5.0	5.0	4.9	4.8	4.6	4.3	4.0	4.0
1150	4.9	4.6	4.5	4.5	4.6	4.8	5.0	5.1	5.1	5.0	4.9	4.7	4.7
1550	4.8	4.8	4.7	4.5	4.0	4.0	4.2	4.4	4.4	4.3	4.2	4.0	4.0

Summer

Wind vane	2.7	2.5	2.4	2.4	2.4	2.5	2.9	3.2	3.6	3.9	4.3	5.0	5.0
100	5.8	6.2	6.3	6.4	6.2	5.8	5.4	5.2	5.3	5.6	6.2	6.4	6.6
200	7.2	7.4	7.4	7.4	7.2	7.0	6.5	6.0	5.8	5.8	6.2	6.5	6.7
300	7.8	7.8	7.6	7.6	7.5	7.4	7.0	6.6	6.1	6.1	6.1	6.1	6.5
600	7.6	7.5	7.4	7.4	7.4	7.4	7.3	7.2	7.0	6.8	6.6	6.6	6.6
850	7.6	7.4	7.2	7.2	7.4	7.5	7.5	7.5	7.5	7.3	7.1	6.9	6.9
1150	7.4	7.2	7.1	7.3	7.5	7.8	8.0	8.0	7.9	7.6	7.4	7.1	7.1
1550	7.6	7.7	7.7	7.8	7.8	7.9	7.9	7.9	7.9	7.9	7.8	7.7	7.6

Fall

Wind vane	3.6	3.6	3.5	3.5	3.5	3.5	3.6	3.8	3.9	4.1	4.5	5.0	5.0
100	7.0	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.7	6.8	6.8	7.0	7.1
200	5.3	5.3	5.2	5.1	5.1	5.0	4.9	4.7	4.6	4.5	4.5	4.5	4.5
300	5.2	5.1	5.1	5.0	5.0	5.0	4.8	4.6	4.5	4.3	4.0	3.7	3.7
600	5.2	5.2	5.2	5.2	5.3	5.3	5.3	5.4	5.3	5.2	5.1	4.9	4.7
850	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.2	5.0
1150	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.2	5.0
1550	5.2	5.2	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.2	5.2	5.2	5.2

Winter

Wind vane	4.4	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.6	4.8	4.9	4.9
100	6.9	6.9	6.9	7.0	7.0	7.0	7.0	7.0	7.1	7.0	7.0	7.1	7.2
200	5.0	5.0	5.1	5.1	5.1	5.2	5.2	5.2	5.0	5.1	5.0	4.9	4.9
300	5.8	5.8	5.8	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.7	5.6	5.5
600	5.1	5.2	5.2	5.4	5.5	5.6	5.7	5.6	5.5	5.4	5.4	5.3	5.3
850	5.4	5.4	5.5	5.6	5.7	5.8	5.7	5.6	5.5	5.4	5.7	5.7	5.6
1150	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.5
1550	5.8	5.8	5.8	5.8	5.7	5.6	5.6	5.6	5.6	5.6	5.6	5.7	5.8

Table 7 (Cont'd)

Time (hours)													
13	14	15	16	17	18	19	20	21	22	23	=	9	A
Spring													
6.0	6.0	5.9	5.8	5.6	5.3	4.9	4.5	4.5	4.4	4.3	4.9	2.1	
7.5	7.5	7.5	7.4	7.3	7.3	7.3	7.4	7.2	7.1	7.0	7.1	0.8	
7.7	7.6	7.6	7.5	7.5	7.7	8.1	8.4	8.5	8.5	8.3	7.9	0.9	
7.6	7.6	7.5	7.4	7.3	7.8	8.3	8.8	9.0	9.2	9.4	8.2	2.2	
7.9	8.0	7.9	7.9	8.0	8.2	8.7	9.0	9.2	9.4	9.5	8.6	1.6	
8.4	8.4	8.2	8.2	8.2	8.4	8.5	9.1	9.2	9.4	9.4	8.8	1.2	
8.5	8.5	8.4	8.3	8.2	8.3	8.3	8.6	8.8	8.9	9.0	8.7	0.9	
8.8	8.7	8.7	8.6	8.6	8.5	8.5	8.5	8.6	8.7	8.8	8.9	0.9	
Summer													
5.1	5.1	5.0	4.9	4.9	4.1	3.7	3.1	3.0	2.9	2.8	3.6	2.7	
6.6	6.6	6.6	6.6	6.4	6.4	6.4	6.3	6.0	5.8	5.8	6.1	1.4	
6.8	6.7	6.8	6.7	6.5	6.7	7.0	7.2	7.2	7.2	7.2	6.8	1.6	
6.6	6.7	6.7	6.6	6.5	6.7	7.2	7.5	7.7	7.9	8.0	7.0	1.9	
6.6	6.6	6.8	7.0	7.1	7.2	7.6	7.7	7.8	7.8	7.8	7.2	1.2	
7.0	7.1	7.2	7.4	7.6	7.6	7.8	7.8	7.8	7.8	7.8	7.4	0.9	
7.8	7.9	7.1	7.1	7.2	7.4	7.6	7.6	7.6	7.6	7.5	7.4	1.0	
7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.6	7.6	7.6	7.7	0.4	
Fall													
5.1	5.1	5.0	4.6	4.2	4.1	3.9	3.3	3.8	3.7	3.6	4.2	1.6	
7.1	7.0	6.9	7.0	7.0	7.2	7.3	7.4	7.3	7.2	7.0	7.0	0.7	
7.4	7.3	7.4	7.6	7.9	8.1	8.3	8.4	8.5	8.4	8.3	7.9	1.2	
7.7	7.8	8.0	8.2	8.5	8.8	9.0	9.2	9.3	9.3	9.3	8.6	1.6	
8.6	8.5	8.7	8.9	9.0	9.1	9.4	9.6	9.5	9.4	9.3	9.1	1.1	
8.8	8.7	8.7	8.9	8.9	9.0	9.1	9.1	9.1	9.0	8.8	9.0	0.6	
8.9	8.8	8.8	8.8	8.8	8.9	9.0	9.0	9.0	8.9	8.8	8.9	0.4	
9.3	9.3	9.2	9.2	9.2	9.2	9.1	9.0	9.1	9.2	9.2	9.2	0.3	
Winter													
5.0	5.0	4.9	4.8	4.7	4.7	4.6	4.8	4.6	4.5	4.5	4.8	0.2	
7.0	6.9	6.9	6.9	7.0	7.1	7.2	7.3	7.2	7.0	7.0	7.0	0.4	
7.8	7.6	7.7	7.8	7.9	8.0	8.2	8.3	8.3	8.2	8.1	8.0	0.7	
8.3	8.2	8.2	8.4	8.5	8.7	8.8	8.9	8.9	8.9	8.8	8.7	0.9	
9.3	9.3	9.2	9.2	9.4	9.4	9.5	9.4	9.4	9.3	9.3	9.4	0.5	
9.6	9.5	9.4	9.3	9.2	9.4	9.5	9.6	9.5	9.5	9.4	9.5	0.6	
9.6	9.6	9.6	9.7	9.7	9.7	9.7	9.7	9.6	9.6	9.6	9.6	0.1	
9.9	10.0	10.0	10.0	9.9	9.8	9.8	9.8	9.5	9.8	9.8	9.8	0.5	

Table 8

Many Years' Average Wind Speed ( $\bar{v}$ ) and Its Error ( $\sigma'_{\bar{v}}$ ) ( $n$  = Number of Terms in Series,  $\sigma'^2_{\bar{v}}$  = Mean Square Deviation in Speed).

Month	Time (hours)							
	02				14			
	$n$	$\bar{v}$	$\sigma'_{\bar{v}}$	$\sigma'_{\bar{v}}$	$n$	$\bar{v}$	$\sigma'_{\bar{v}}$	$\sigma'_{\bar{v}}$

100 m								
January.....	147	6.6	3.3	0.3	150	6.7	3.0	0.2
February.....	134	6.6	3.0	0.3	136	6.9	3.3	0.3
March.....	140	7.0	3.4	0.3	143	7.7	3.5	0.3
April.....	142	7.1	3.3	0.3	139	7.4	3.7	0.3
May.....	147	6.9	3.2	0.3	143	7.5	3.5	0.3
June.....	147	6.2	3.0	0.2	147	6.6	3.1	0.3
July.....	146	6.8	3.3	0.3	149	6.8	3.0	0.2
August.....	147	6.4	2.8	0.2	149	6.6	2.9	0.2
September.....	144	6.2	2.5	0.2	140	6.6	2.8	0.2
October.....	151	7.0	2.8	0.2	149	7.2	2.8	0.2
November.....	145	7.8	3.5	0.3	143	7.1	3.5	0.3
December.....	153	7.5	2.9	0.2	144	7.0	2.8	0.2

850 m								
January.....	141	9.2	4.6	0.4	149	9.7	4.8	0.4
February.....	129	9.9	4.8	0.4	129	9.6	5.0	0.4
March.....	141	9.3	4.8	0.4	137	9.5	4.9	0.4
April.....	141	9.0	4.2	0.4	140	7.9	4.2	0.4
May.....	140	8.2	4.2	0.4	147	7.9	4.4	0.4
June.....	146	7.0	3.8	0.3	143	6.9	3.4	0.3
July.....	146	7.1	3.9	0.3	147	7.0	3.7	0.3
August.....	146	7.5	3.9	0.3	147	7.4	3.5	0.3
September.....	139	8.0	3.6	0.3	138	7.3	3.9	0.3
October.....	149	9.1	4.4	0.4	146	8.6	4.4	0.4
November.....	138	9.4	4.3	0.4	140	10.0	4.9	0.4
December.....	148	9.5	4.8	0.4	138	9.3	4.5	0.4

Let us now return to the isopleths of the deviations  $\sigma'_{\bar{v}}$  represented in Figs. 1-4.

It is easy to observe that in the spring (Fig. 1), at the Earth's surface, the diurnal maximum of speed falls at 1300-1400 hours, while the minimum occurs at 0300-0400 hours. At a height of an average of around 100 m, there is found the level of the reversal of the wind (zero isopleth) above which the speed has a diurnal pattern, opposite to that which occurs at the Earth's surface: the maximum in speed is recorded at 2200-2300 hours, while the minimum, perceptibly deformed by the influence of the near-ground maximum, extends between 1100 and 1700 hours. This second type of the diurnal pattern is expressed most clearly in the 300-500 meter layer. Within the limits of this layer, in proportion to the increase in height, the nocturnal maximum is shifted to 0400-0500 hours, while the daytime

minimum, becoming less distinct, is maintained for about the same time interval.

Starting from a height of 800-900 m, we find a third type of diurnal pattern in wind speed with two maximums (at 0700-0900 and 2200-2300 hours) and with two minimums (at 0200-0300 and 1700-1800 hours).

An analogous pattern occurs in summer (Fig. 2). However, in this season, the nature of the diurnal variations nevertheless differs from the spring season in certain features: by a somewhat raised level of wind reversal during the day, and by a lowering at night, by an earlier arrival (in the first half of the day), of the phases of the diurnal pattern, and by a perceptible decrease in the depth of the layer with two maximums and two minimums.

In autumn (Fig. 3), there occurs a further "subsidence" of the layer with a dual diurnal pattern of speed, also propagating to the subjacent layers. At a height of 1700-1800 m, the morning maximum is replaced by a minimum, indicating the appearance of a further (fourth) type of diurnal pattern in wind speed.

The latter circumstance is portrayed quite lucidly in Fig. 4, typifying the diurnal variations in the speed in winter. As is obvious, during this season, at a height of 1300-2000 m, we find a diurnal wind speed pattern with one maximum (at 1400-1900 hours) and one minimum (at 0700-0900 hours). With regard to the first three types of the diurnal pattern, they are also retained in a weakly expressed form in the winter, as a whole not emerging beyond the limits of the 1,000 m level.

A more definitive concept of the basic types of diurnal wind speed pattern is provided by the curves constructed for several levels with distinctly manifested typical variations in the speed during a 24-hour period (Fig. 5). Comparing the appropriate curves pertaining to the various seasons, it is easy to detect, on the one hand, the basic similarity of the diurnal fluctuations in speed during the entire year, and on the other hand, the essential differences between them, especially in respect to value of amplitude.

Naturally, the differences in the diurnal pattern of the speed at various levels are linked with the dissimilar nature of the vertical wind distribution at different hours of the day. As is shown in Fig. 6, from the Earth's surface to 100-200 m, wind speed rises abruptly with height, while above the indicated level, it behaves differently: in the warm

season of the year in the morning, it increases gradually, while around midnight, it decreases slowly; during the day, the gradual drop is alternated twice by a fairly rapid rise. In the winter, the vertical wind profile changes but little during a 24-hour period.

The distribution of the mean wind speed in the entire depth of the boundary layer over an entire 24-hour period can be traced easily with the aid of the isopleths represented for each season, and depicted in Figs. 7-10. Without going into a detailed analysis of this distribution, let us note only certain of its characteristic features.

In the spring (Fig. 7), the maximum mean wind speed value (9.5 m/sec) is recorded at around midnight at a height of 500-700 m. Only in the morning, at the topmost level of the boundary layer (1800-2000 m) does the wind speed attain approximately the same value. In summer (Fig. 8), the nocturnal maximum (8.0 m/sec) occurs at a height of 300-500 m, while the morning maximum occurs at 1300-1600 m. Between the morning and night maximums, in the spring and summer, the daytime maximum is well-expressed. Its axis passes through the entire boundary layer, shifting from the second half of the night at the Earth's surface to the evening hours at the upper levels. The second minimum is recorded at night at the height of 1,100-1,500 m.

A similar although less distinct distribution in wind speed occurs in the autumn (Fig. 9). During this season, the night-time minimum proves to be extended greatly through time; and the nocturnal maximum (19.6 m/sec) shifts to the evening hours.

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In winter (Fig. 10), the wind speed distribution features typical of the boundary layer are traced only to a height of around 1,000 m. Above the indicated level, they are quite imperceptible. The sole feature which attracts attention here is the slight morning minimum, extended through time and in height, encompassing a part of the night and almost the entire first half of the day. Incidentally, this minimum pertains to the heights which during the cold season already prove to extend beyond the limits of the boundary layer.

In general, such is the pattern of the diurnal wind speed variations in the lower 2-kilometer layer of the atmosphere. Essentially, it reduces to the fact that in proportion to distance from the Earth's surface, we have a successive alternation of three-four, as a rule, opposite, types of the diurnal pattern of wind speed. The average height and the depth of the layers (to which any given type of diurnal pattern is inherent)

depend appreciably on the season. The variations in speed with height are dissimilar at various hours of the day.

The results obtained from analyzing the actual observations thus indicate that the typical diurnal wind speed pattern is manifested in a fairly distinct form in the south of the Eastern-European plains (Kharkov). This agrees fully with the existing concepts about the reasons underlying the phenomenon under consideration.

As is known, the first explanation of the diurnal wind speed pattern was given independently by Espi, Keppen and Voyeykov. As early as 1884, the latter had indicated the necessity (for explaining the diurnal pattern) "of reviewing the relation of the lower air layers to the superjacent ones" [4].

According to the Espi-Keppen theory, having enjoyed great popularity for a long time, the diurnal pattern of the wind speed is caused by the exchange of the lower air masses, slowed in their motion, with the upper, more mobile masses. This exchange occurs most strongly immediately after noon, when the vertical convection and its accompanying turbulence attain the maximum intensity. Therefore, around noon, at the Earth's surface, a maximum is recorded, while in the superjacent air layer, a minimum of the wind speed is registered. The quantity of motion, redistributing among the layers with a varying wind speed, is generally retained during this time. In the same way, we also can explain the reversal of the diurnal pattern aloft, and its weakness above the oceans, where the intensity of convection scarcely changes during a 24-hour period [13].

Distinguished as a whole by a recognized orderliness, this theory nevertheless proves inadequate for explaining certain important aspects of the phenomenon. Thus, the layer in which the wind speed lacks during the day is many times deeper than the near-ground layer, where the speed is intensifying. In view of this, the total quantity of motion can not be preserved. Obviously, during the day, it decreases, while at night it increases. Hence, the Espi-Keppen theory does not explain the differences in the vertical extent of the layers with reversed diurnal patterns.

The assumption exists that during the day in the atmosphere, which is heating up and expanding, a certain accumulation of potential energy occurs, which in the evening and at night is "realized", transforming to kinetic energy of air motion [27]. Obviously, this effect is superimposed on the above-indicated effect of convection.

According to another viewpoint, the basic reason for the great depth of the upper layer, where the wind speeds slacken during the day, is the wind's freshening during the day at the Earth's surface, causing an increased energy dissipation in the near-ground layer, and a reduction in the quantity of motion up to considerable heights [21].

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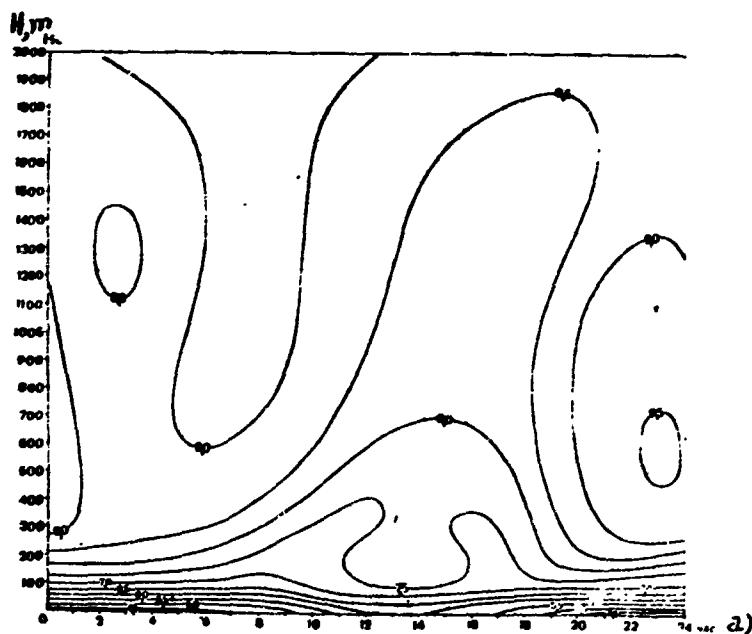


Fig. 7. Isopleths Indicating Mean Wind Speed. Springtime.  
Key: a) hours



Fig. 8. Isopleths Indicating Mean Wind Speed. Summer.  
Key: a) hours.

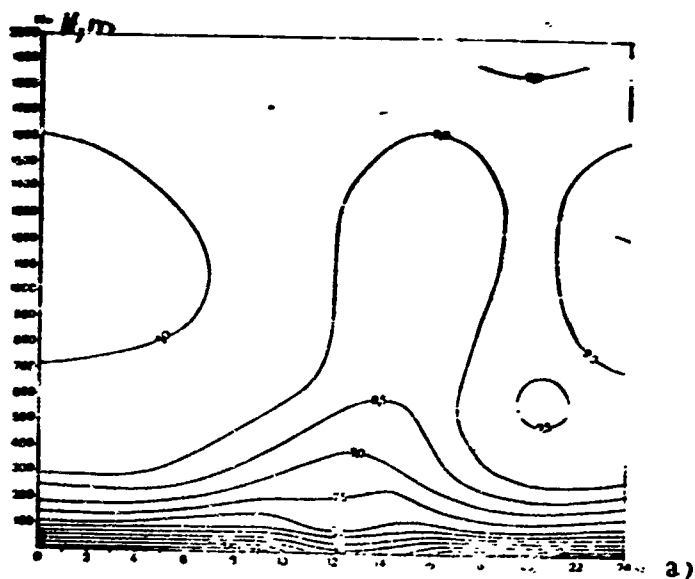


Fig. 9. Isopleths of Mean Wind Speed. Autumn.  
Key: a) hours.

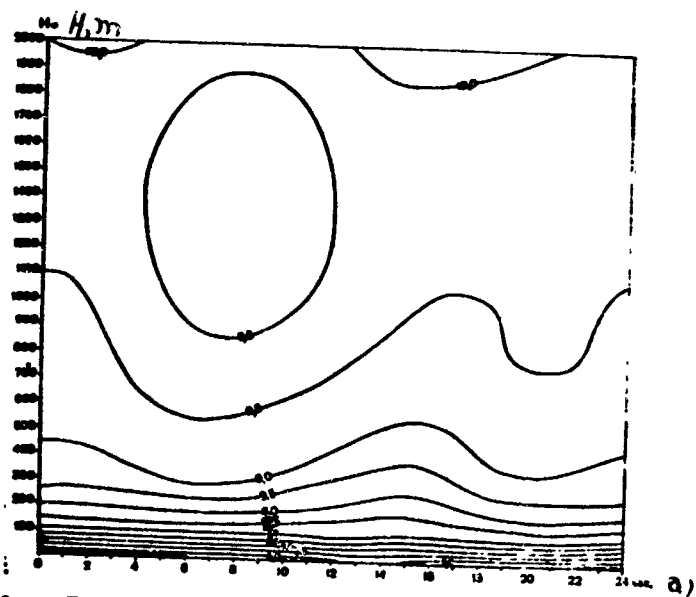


Fig. 10. Isopleths Depicting Mean Wind Speed. Winter.  
Key: a) hours.

It is also considered that, along with the daytime development of the convection and turbulence, the cause for the diurnal pattern of wind speed (and direction) can be found in the diurnal variations of the additional baric gradient. Under known conditions, the latter seemingly appears in the atmosphere as a supplement to the basic baric gradient, directed in accordance with the general arrangement of the isobars [1]. The additional baric gradient causes an additional vector of wind speed, which is superimposed geometrically with the base velocity vector, varying its direction and value.

Unfortunately, not one of the suggested qualitative systems can explain all the phenomenon's details. Therefore what is needed is a strict quantitative theory, but its construction presents appreciable difficulties.

The first attempt at a mathematical explanation of the diurnal pattern of wind speed was made by B. I. Izvekov. However, assuming the coefficient of turbulent viscosity to be unvarying with height, the results he obtained were not very satisfactory [2].

M. Ye. Shvets solved the problem of the diurnal pattern of wind speed, hypothesizing that the coefficient of turbulent viscosity increases to a certain height, then remaining constant. He considered this coefficient to be a periodic time function with a 24-hour period [28].

The result obtained by Shvets agrees better with the observations. Nevertheless, the explanation of the diurnal pattern requires a further, more detailed theoretical development and verification. It is apparent that the empirical studies should also facilitate this.

In conclusion, I wish to divert attention to certain specific results of our analysis, which seem somewhat unexpected in the light of the existing concepts.

Above all, what is very striking is the circumstance that the layers with the clearly expressed diurnal variations in speed attain the maximum height in the spring months rather than in the summer. This phenomenon, unusual at first glance, proves quite natural upon closer examination, since in a large part of the European territory of the USSR, the height of the boundary layer and the coefficient of turbulent mixing reach the maximal value specifically in spring [16]. At this time of the year, the distribution of the meteorological elements in the boundary layer is affected equally strongly by the thermal and the dynamic factors (in summer, the dynamic factor has a

lesser value in view of the wind's slackening in the annual pattern).

The relatively early arrival, in summer, of the phases of the diurnal pattern in the forenoon hours is generally known and easily explainable. However, in our view it is not simple to explain the fact that the increase in the duration of the day and the related increase in the role of the thermal factor does not lead to a later advent of the afternoon phase (it would appear that the latter should occur on the strength of the phenomenon's physical logic). In this sense, the mutual convergence of the diurnal pattern's phases in the cold period, when the effect of the thermal factor becomes barely perceptible, appears more natural.

The results obtained do not agree entirely with the popular opinion to the effect that in the boundary layer, the wind speed always increases with the height. Even the observations conducted in Kharkov and averaged for 5 years permit us to detect in the warm half of the year a considerable decrease in the wind speed with height, starting from various levels at different times of the day. Moreover, these observations indicate quite definitely that around midnight, the maximal values of mean wind speed during a greater part of the year do not occur in the upper levels of the boundary layer, but at a height of only 300-500 m in all. /118

Let us recall that the maximum of wind speed at a height of 300-500 m was first discovered by M. M. Rykachev. However, both Rykachev and subsequently Molchanov, just as certain contemporary authors [27] assumed it to be weak, evidently owing to the scantness of the available data or as a result of their diurnal averaging. Actually, however, as the observations conducted in Kharkov indicate, this maximum in the hours around midnight, especially in spring and summer, is not only sufficiently strong but is also basic.

A certain slackening of the wind with height is evidenced by the data for Pavlovsk, obtained by another method and averaged for another 5-year period [15].

We should also stress that, according to the analysis conducted, the average wind speed in the upper layers of the boundary layer in certain seasons can be less at night and more in the first half of the day. It is therefore considered that the judgment, expressed half a century ago by V. A. Khanovskiy [26] and repeated until this time, to the effect that to a height of at least 3 km, the maximum wind speed usually occurs at night, while the minimum is usually during the day, needs some refinement. Let us incidentally comment that

referring to Khanevskiy, the modern authors do not stipulate that in the given case, he relied on the results of kite observations, taken in an annual averaging. Khanevskiy himself considered that it was necessary to stress this aspect.

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# DATA INDEXING PAGE

<b>01-ACCESSION NO.</b> TT9001427 <b>02-DOCUMENT LOC</b>		<b>03-TOPIC TAGS</b> atmospheric wind field, wind speed duration, wind velocity		
<b>04-TITLE</b> CONTINUOUS DURATION OF WIND SPEEDS UNDER THE CONDITIONS OF THE PLAINS AREAS IN THE USSR				
<b>05-SUBJECT AREA</b> 04				
<b>12-AUTHOR/CO-AUTHORS</b> ANISIMOVA, T. N.				<b>18-DATE OF INFO</b> -----68
<b>03-SOURCE</b> MOSCOW. NAUCHNO-ISSLEDOVATEL'SKIY INSTITUT AEROKLIMATOLOGII. TRUDY (RUSSIAN)				<b>48-DOCUMENT NO.</b> HT-23-261-69 <b>49-PROJECT NO</b> 72301-78
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## ABSTRACT

(U) A discussion is presented of methods used to determine the characteristics of the duration of sustained wind speeds over plains areas in the Soviet Union. The data were taken from the Spravochnik po klimaty SSSR (Handbook on the Climate of the USSR), Part III, and consisted of measurements made at 28 stations located in areas of various types of shelter and terrain and representing such widely distant areas as Dickson Island in the Arctic to Kiev in the Ukraine and Irkutsk in Central Asia. Wind-speed intervals for open flat terrains were less than or equal to 2, 4; and greater than or equal to 5, 8, 12, 16, and 20 m/sec. Modal values of the frequency of wind-duration limits (cases in which modes for hourly intervals and those for more than 1 hr were calculated) were used to construct distribution curves. Analysis of these curves failed to show any significant differences in them either for the various stations, wind-speed limits, or for seasons, i.e. the distribution curves related to a single law of distribution in which only the numerical parameters varied. Orig. art. has: 1 figure, 3 tables, and 2 formulae.

# DATA INDEXING PAGE

01-ACCESSION NO. 02-DOCUMENT LOC <b>TT9001428</b>		20-TITLE TAGS <b>atmospheric boundary layer, wind field, wind gradient, wind velocity</b>		
03-TITLE APPROXIMATE CALCULATION OF WIND SPEED IN THE 100 METER ATMOSPHERIC SURFACE BOUNDARY LAYER FOR THE CEN- TRAL REGIONS OF EUROPEAN *		04 <b>04</b>		
04-SUBJECT AREA				
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ABSTRACT \* 09 USSR

(U) An approximate calculation procedure is described for the determination and characterization of the changes in wind speed with height in the lower 100-m layer of the atmosphere over the forest and forest-steppe (southeast of the Oka River) terrains of central European USSR. These variations are determined by comparing wind speeds measured at vane-heights with those measured at h equals 100 m from radiosondes and pilot balloon launch sites, and pilot balloons (77 weather stations, 7 pilot launch sites, and 18 radiosonde stations). Since station characteristics varied widely, the stations were grouped by such characteristics as type of terrain (forest of forest-steppe), openness (visual range, degree of shelter), type of relief, proximity to water body and type of shoreline, and nearness to populated areas. The mean annual wind speed and the diurnal amplitude of the speed in July were taken into account in the station grouping process. The results of the study are presented in the form of graphs, tables and extensive appendices which show in detail the monthly, daily mean, daytime, and nighttime relationships of wind speeds to 20 types of weather station positions. Orig. art. has: 4 figures, 10 tables, and 4 formulas.

# DATA HANDLING PAGE

01-ACCESSION NO. 10-DOCUMENT LOC		20-TOPIC TAGS		
TT9001429		atmospheric wind field, atmospheric boundary layer, planetary boundary layer, atmospheric turbulence		
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07-SUBJECT AREA				
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## ABSTRACT

(U) A method is proposed whereby diurnal variations in boundary layer wind speeds can be determined by combining rawinsonde measurements made at 6-hr intervals in a 24-hr period with those made with pilot balloons in periods intermediate within these main intervals. In this method the results obtained from the pilot balloon measurements are reduced to the rawinsonde data, using a method involving the differences in long-term values of the mean diurnal wind speeds. The procedure involves the individual computation of the long-term mean diurnal wind speeds at fixed heights from speeds obtained in four equally spaced rawinsonde ascents and for four other identically spaced periods in which pilot balloon observations are made. The difference between these two values is the error of the pilot balloon observations relative to the rawinsonde measurements (with the opposite sign). It is assumed that the difference is stable for all of the observation periods, the mean wind speed for a given period obtained from long-term pilot balloon observations can be reduced to the value of an adequately "mean rawinsonde measurement" for the same period, i.e. Orig. art. has: 10 figures, 8 tables, and 5 formulas.